UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

BERKELEY, CALIFORNIA

TOLERANCE OF EUCALYPTUS FOR ALKALI

WITH PARTIAL REPRINT FROM BULLETIN 196

By R. H. LOUGHRIDGE

BULLETIN No. 225

(Berkeley, Cal., October, 1911)

SACRAMENTO
FRIEND WM. RICHARDSON - - - SUPERINTENDENT OF STATE PRINTING
1911

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TOLERANCE OF EUCALYPTUS FOR ALKALI.

By R. H. Loughridge.

During the past few years the interest in Eucalyptus growing has been widespread over the State, because of the increasing scarcity of timber trees for commercial purposes, the prospect of ''splendid financial returns'' to growers after the lapse of fifteen or more years and because of the special adaptation of California climate and soil to that group of trees.

It goes without saying that for all plants and trees the better the soil the better the growth, and Eucalyptus is not an exception. It attains its most rapid growth in a loose loam soil that contains an abundance of the plant food elements, potash, lime, magnesia, iron, phosphoric acid, and especially of humus with high nitrogen content; a soil of ten or more feet in depth in which root development and activity may be free and unrestricted by hardpan, bedrock, gravel, or high water-table; a soil having a good moisture supply and good aeration; a soil that is warm and capable of facilitating bacterial activity in the formation of nitrates from the organic nitrogen of humus. But lands of this nature are usually far more valuable for other cultural purposes than the growth of Eucalyptus trees, and for this reason the culture of the latter on the large scale is often being done or attempted on tracts that seem to be unfitted for general farming purposes.

It thus happened that attention was called to the large tracts of alkali land, that occur in those portions of the valleys of the State where a low rainfall and other conditions have favored the accumulation of these soluble alkali salts. It is well known that plants both small and large can withstand the effect of only certain amounts of these salts, and that they also vary in their power of tolerance, some being very sensitive and others quite immune except to very large amounts. Citrus trees, for instance, seem to be seriously affected by 2,500 pounds of common salt per acre, while grapes grow fairly well in many times that amount.

Recognizing this fact the eucalyptus grower quickly appealed to this station for information as to the amount of alkali the eucalyptus would tolerate while making good growth. It has unfortunately happened that while we have for the past fifteen years made observations regarding very many other cultures, such as grain crops, alfalfa, fruit trees, etc., only casual attention has been given to the Eucalyptus; in fact, the only analysis of alkali in a soil growing these trees which we were

able to find was that from the Tulare Station; and a search of publications from other states and countries gave no record of such an examination, the various writers on the planting and growing of eucalypts having failed to note the alkali side of the question. Even at the Tulare Station, where quite a number of large Eucalyptus trees are growing, no examination was considered important until the question of tolerance came from growers.

We then took up the task of trying to ascertain as near as possible the alkali tolerance of the chief species of the tree, working thereto in several directions; first to ascertain the maximum amount in which the trees were growing and doing well, and the minimum amount of each salt where they had succumbed to the effects of the alkali alone; second, to examine new plantations and nurseries in which the alkali was plainly present; and third, to select a large alkali spot in which to plant several of the more important species in alkali of varying strengths.

Mr. Frank E. Johnson, assistant in the soil laboratory, was intrusted with the work of visiting the plantations of eucalypts in the alkali regions of the State, noting tree conditions and collecting soils for examination. He also made the greater number of alkali analyses that are given in this report.

The identification of species from samples brought in was largely done by Prof. H. M. Hall, botanist of this station; unfortunately, it was impossible to recognize the species of many of the specimens, and the results of the examinations of soils in which these were growing were thus of no practical value and are omitted from this report.

The work, however, upon which we relied chiefly in our study of the alkali tolerance of the eucalypts was with seedlings planted in the Tulare Station, and this was carried on under the supervision of the foreman, J. T. Bearss.

CONDITIONS TO BE MET IN THESE INVESTIGATIONS.

The investigation of the tolerance of alkali on the part of any culture is a matter of great difficulty because of the impossibility of eliminating the many causes other than alkali that might produce injury, disease and death, such as insects, shallowness and bad physical conditions in the soil, improper water supply, climatic troubles, etc. All of these must be considered when studying the question, and they make the effort to arrive at correct, or even approximately correct conclusions, especially difficult. To these must be added the irregular and broad extension of the root systems, and the irregular distribution in the soil, both downward and laterally, of the alkali salts and of each individual salt; these could in large measure be controlled or eliminated by planting in a large number of boxes of proper sizes in which certain percentages of alkali salts are thoroughly intermixed with the soil, the roots held

in contact with the alkali, and water conditions kept in control, but even this would be attended with uncertainties and would have to be extended over several seasons, before conclusions could be definitely reached.

In the field examinations, therefore, we have found it unsafe to claim that a tree or plant has been injured or killed by the amount of alkali in its soil (except of course the amount be enormous), unless corroborated by a number of instances where soil conditions are perfect. We can only ascertain the *highest amount* of each particular alkali salt or combination of salts occurring in the upper few feet of the soil in which the plant or tree is apparantly unharmed, thus fixing for the time being its maximum of tolerance; this maximum may subsequently be raised by other observations. If other individuals of the same species are suffering or injured in soils containing less amounts of the salts than the supposed maximum, then we must attribute the injury to other causes than alkali alone.

A very large number of examinations are therefore necessary to ascertain this maximum because of the uncertainty of the strength of alkali in each locality. Thus, in this Eucalyptus investigation, we have made several hundred analyses to ascertain the amount and composition of the alkali salts under as many trees.

If alkali consisted of but one salt the study of toleration would be quite simple; but we find that there are several salts, each having a different effect and behavior, which tend to complicate the study with reference to plants and trees. These salts are sulfate of soda or glaubers salt, carbonate of soda or sal soda and chlorid of sodium or common salt, together with more or less of sulfates of magnesia and lime and nitrates of soda and magnesia. The three first named are however recognized as *the alkali salts,* and are alone considered when alkali is mentioned.

Difference in Action of Alkali Salts.—Each salt has its influence on plant growth, but in different degrees of intensity and in nature of action; and this of course still further complicates the study of tolerance on the part of the plant. The sulfates seem to be rather inert for any direct injury; being very soluble in water, they probably enter the plant cells with solutions of plant food, and if in very large amounts interfere with the proper assimilation and action of the food; or by accumulation as a soil crust they may interfere with the functions of the plant roots.

Common salt is with some cultures probably the most to be feared of the three alkali salts, not so much, perhaps, because of any direct action on the plant, but because of its injurious influence on important microorganisms in the soil, its action through a greater depth than the carbonate, its action when in larger amounts in preventing a normal water supply and consequent starvation of the plant, and in the fact that the

injury can only be prevented by its removal from the soil by thorough leaching.

The carbonate of soda is strongly caustic or corrosive, attacking the root-hairs and the tender bark of the root crown, girdling it and preventing the rise of sap into the plant. It, therefore, acts most energetically near the surface of the soil, and, fortunately, may be here easily neutralized by conversion into sulfate on the application of gypsum, as long ago recommended in the publications of this station.

These salts occur together in greatly varying proportions through the soil column downward and laterally because of differences in the ease with which they move from point to point; the sulfates because of their crystalline form rise rapidly in the soil and with the chlorids occur chiefly in the upper foot; while the carbonate occurs more generally diffused downward. The effect on the plant is therefore largely influenced by the amount of each salt in the soil and their relative proportion; thus forming a problem the more complex as the effects of the salts depend largely upon the physical nature of the soil.

Irregular Distribution of Alkali.—The irregular distribution of the alkali as a whole and of each salt throughout the soil was an especial disturbing element in this investigation. Not only is this the case in a vertical column of four or more feet, but we find the same irregular distribution in a horizontal section. This is shown in the analyses of samples from the cross-section of an alkali plot in the Tulare Station made a number of years ago by C. A. Colmore, and reported in the report of this station for 1902:

PERCENTAGE COMPOSITION OF SALTS IN AN ALKALI SPOT.

Depth.	32 feet from center.				16 feet from center.				Center of spot.			
	Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
First foot	.74	.01	.14	.89	1.02	.01	.17	1.20	1.09	.01	.01	1.11
Second foot	.05	.03	.01	.09	.36	.01	.03	.40	.23	.02	.01	.26
Third foot	.03	.01	------	.04	.05	.01	.01	.07	.14	.01	.01	.16
Fourth foot	.02	.01	------	.03	.05	.01	------	.06	.08	.01	------	.09
Average	.21	.02	.04	.27	.37	.01	.05	.43	.39	.01	.01	.41

These tables are more valuable in illustrating the irregular downward distribution than the horizontal, for the holes were dug at distances of sixteen feet from each other. On other pages of this bulletin will be found a table and diagram on which are shown the percentages of alkali found at distances of but a few feet in all directions, and which very forcibly illustrates this rapidly changing composition. In fact,

we believe that columns of alkali soils but a few inches apart would show the same variability in amount and composition of its alkali.

In this table there is laterally more of total salts and of chlorids and somewhat less of carbonates and sulfates at 16 feet from the center than in the center, while at 32 feet there is a falling off in total salts, sulfates, and chlorids, but an increase in the carbonates.

In the vertical columns the alkali is concentrated in the first foot, but the carbonate has its highest percentages in the second foot.

It is chiefly this irregular distribution of each salt that makes difficult the task of arriving at definite conclusions on the toleration of any plant, and shows the importance of taking the soil samples in close proximity to the plant or tree.

Alkali Exists in small instead of very large Areas.—Another condition to interfere with the investigation is the fact that alkali occurs only in spots and of varying strengths. These spots are often but a few feet in diameter; hence trees near together may be growing under entirely different alkali conditions and the amount tolerated by one tree may not be the same that occurs beneath the others.

This condition is shown in the small tract of young trees planted on the Tulare Station. It is this condition that makes it inadvisable to present the alkali percentages on a map, for small spots or areas are usually far apart with larger intermediate tracts of land that may be nearly or quite free from alkali. Of course in some sections of the State, especially in the trough connecting the lakes that lie in the upper part of the San Joaquin Valley, the alkali is quite continuous, but even then in varying amounts from one hundred thousand pounds per acre in six feet to so low an amount as to insure crop productiveness.

To this fact combined with the irregular distribution of the salts in amounts and kinds is due the great difficulty in selecting proper soil samples.

Movement of Alkali in the Soil.—Another factor to be regarded in the problem of tolerance is the movement or rise and fall of alkali salts at different seasons of the year due to water evaporation. In the alkali regions of California there are really but two seasons, the *winter or wet season,* from November to April, during which time the entire yearly precipitation occurs, and the *summer or dry season,* when there is practically no rainfall. The salts of alkali being extremely soluble in water, therefore, are dissolved in winter rain and pass downward with the water to depths dependent on the physical condition of the soil and the amount of rain, but usually three or four feet.

During this wet period of course the roots near the soil surface are relieved of the influence of the alkali and may attain good development before the hot rainless summers produce an upward capillary movement

of the water and alkali, and a concentration of the latter in the upper foot or two, where damage is done to the roots.

All of these conditions must be considered when we study the plant, together with the annual or seasonal rainfall as indicating to what depth the water may percolate and carry the salts with them. A precipitation of an inch of rain will penetrate 4 or 5 inches in a loam soil and less in a clay soil. A continuous fall of 5 inches of rain would therefore wash the alkali down through a depth of probably 18 or 20 inches. Should this be followed by a warm, protracted dry spell the alkali water would doubtless rise by capillarity to be again carried down by subsequent rains. This rise and fall of the alkali salts produces a critical period in the life and growth of the young trees with their root systems limited in length and spread, and subject to attack by the alkali and more especially by the caustic carbonate. Could the alkali be kept down for some feet in the soil until the young roots become strong, well developed and with a comparatively thick bark the tree may survive alkali of quite a strength. There is but little doubt that many eucalypti now growing in strong alkali soils, have been enabled to secure good, strong root-development during the time that the alkali was several feet below the surface and thus to become partly if not wholly immune to its effect when subsequently concentrated near the surface. When the tender roots reach below the zone of alkali the tree is quite safe from injury. This point of view is emphasized by the native mesquit which we find growing in the strongest of alkali lands, its thick and deep-lying roots being well protected against the influence of alkali by thick, tough bark.

This uncertainty regarding the movement of the several salts, and this irregularity of alkali composition and distribution, was one of the chief sources of trouble in studying the effect on trees and plants, for not until an analysis has been made of the alkali content of the soil can we judge of its strength and percentage composition.

Development of the Eucalyptus Root System.—In addition to the climatic and other difficulties to be met in the study of the influence of the alkali salts upon the life and growth of the eucalypts we have that of the rapid development of the root systems of the tree; this practically limits the time for observation to the earliest stages of growth when the young roots are within the alkali zone.

The Eucalyptus tree develops its root system very rapidly as it grows from the young plant to the large tree. It is a general supposition in California that the tap root reaches, if unimpeded, to a depth below the surface of the soil equal to the height of the tree above ground; this in old trees would be fully 100 feet in alluvial lands. Depths of 60 feet have been reported from southern California. The lateral extension of the roots is well known to be very great, a root one fourth of an inch

thick having been observed by us in an orchard near Riverside, at a distance of 75 feet from the tree and evidently its extension was fully 25 feet further. This large lateral development of the Eucalyptus roots, where the trees have been planted as wind breaks or for ornament, is a well known source of danger to adjacent fruit orchards because of their great absoption of soil moisture; in some cases deep trenches have been dug to cut the Eucalyptus roots and protect the orchard trees.

The Eucalyptus Timber Corporation of Tulare County has made observations of the root development of young trees and some of the results as contained in a pamphlet of the company are here given:

Age of tree.	Height of tree.	Depth of tap root.
15½ months	13 feet 6 inches	16 fect 6 inches
6 months	7 feet	7 feet 11 inches
6 months	6 feet 11 inches	8 feet
6 months	8 feet	8 feet 1 inch

The downward development is even greater in the above young trees than they are usually credited with; and if the same ratio of increase is maintained a tree 100 feet high would have a tap root from 110 to 123 feet below the surface of the ground. This is not to be greatly doubted where depth of soil strata permits, for this deep penetration of the roots of other trees, both ornamental and orchard, as well as of plants and grasses in California soils is of common observation, as reported in previous publications of this Station. The roots of wheat, barley, and the California poppy (*Eschscholtzia californica*) have been followed to depths of thirteen feet in the loam soil of the University Farm at Davis, Yolo County, California.

TEST PLOT FOR EUCALYPTUS SEEDLINGS: TULARE STATION.

The critical period in the life of any plant that has been placed in a soil is when it is very young and when its root system is very delicate and susceptible to injury, and is limited in its development to the surface foot of the soil. When to the ordinary dangers of improper temperature and moisture, poor aeration, severe soil texture and deficiency in plant food, is added that of the effect of alkali, and especially of carbonate of soda, the life of the plant is still more endangered because of the action of these salts on the extremely tender root-hairs and bark of the young roots. As the plant grows older the roots become more woody near the soil surface and are less susceptible to injury, and they also extend to greater depths and with a greatly enlarged and broadened root system; the delicate tips or newest growing parts of the roots are thus farther and farther from the influence of the alkali which usually exists only in the upper four feet. If, then, the young plant can survive the first year or two in an alkali soil there is but little doubt of its ultimate success.

An old tree growing in an alkali spot is a proof either that the alkali contained in the soil around its base was not sufficient to injure the roots when the tree was very young, or that the alkali had been kept below the roots by some system of irrigation or cultivation until their broad expansion and growth downward had carried them out of danger; for it is usually the alkali in the upper foot or two of soil that causes injury. In this report we have therefore laid greater stress on the experiments with Eucalyptus seedlings planted in a spot of alkali soil in the Tulare Station than upon observations upon older trees.

Distribution of Alkali in Soil of Eucalyptus Plot.—A spot of supposedly very strong alkali was chosen near the southwest corner of the Tulare Station tract on which to test the effect of alkali of different strengths upon young eucalypts of the different species chiefly grown in this State. In previous years eucalypts had been planted here, and some of these still remain around the spot, but many had died from various causes. This spot embraced an irregular area of about 150 by 100 feet, and in its center the soil was covered with a coating of alkali salts and was entirely bare of vegetation. A preliminary determination of the strength and distribution of the alkali was made by the analyses of nearly one hundred four-foot soil-columns taken at distances of ten feet in each direction. The results in percentages are given in the accompanying table; and also in the diagram, in which is also presented many subsequent analyses which were made of soils taken very close to the young trees that had been planted. The diagram is shaded to show

at a glance the varying intensities of total salts; the large numbers represent approximately the number of pounds of alkali per acre in a depth of four feet in each shaded area.

ALKALI SALTS IN THE SOILS OF THE EUCALYPTUS TEST PLOT, TULARE STATION.

Taken four feet in depth at distances of ten feet in each direction.

Sulfates	.048	.070	.110	.192	.257	.395	.114	.157	.130	.065	.072
Carbonates	.007	.007	.007	.007	.014	.005	.005	.005	.005	.006	.005
Chlorids	.028	.009	.005	.005	.019	.074	.005	.028	.019	.023	.009
Totals	.083	.084	.122	.204	.290	.474	.124	.190	.154	.094	.086
Sulfates	.058	.076	.048	.174	.290	.257	.425	.193	.104	.137	.094
Carbonates	.005	.003	.007	.009	.009	.012	.002	.010	.009	.005	.007
Chlorids	.005	.009	.009	.009	.005	.009	.009	.005	.005	.009	.009
Totals	.068	.088	.164	.252	.304	.278	.436	.208	.118	.151	.110
Sulfates	.078	.088	.170	.397	.347	.375	.281	.279	.140	.141	.138
Carbonates	.007	.003	.007	.002	.005	.004	.009	.005	.007	.005	.005
Chlorids	.005	.005	.009	.005	.009	.009	.014	.019	.019	.028	.009
Totals	.090	.096	.186	.404	.361	.388	.304	.303	.166	.174	.152
Sulfates	.111	.130	.227	.482	.411	.520	.305	.234	.168	.118	.114
Carbonates	.002	.005	.007	.007	.009	.003	.012	.009	.009	.005	.005
Chlorids	.009	.009	.009	.023	.009	.009	.028	.023	.019	.009	.005
Totals	.122	.144	.243	.512	.414	.532	.345	.266	.196	.132	.124
Sulfates	.110	.116	.191	.226	.460	.330	.331	.184	.164		
Carbonates	.003	.007	.010	.009	.009	.009	.005	.005	.003	Trees	
Chlorids	.009	.005	.005	.009	.009	.009	.019	.009	.009		
Totals	.122	.128	.206	.244	.478	.348	.355	.198	.176		
Sulfates	.168	.184	.148	.152	.222	.318	.187	.193	.165		
Carbonates	.003	.005	.009	.010	.011	.012	.008	.002	.002	Trees	
Chlorids	.009	.009	.009	.009	.009	.009	.009	.009	.009		
Totals	.170	.198	.166	.171	.232	.339	.204	.204	.176		
Sulfates	.103	.123	.167	.182	.186	.119	.116	.111			
Carbonates	.004	.003	.004	.005	.004	.004	.005	.002		Trees	
Chlorids	.005	.009	.009	.005	.009	.009	.009	.009			
Totals	.112	.135	.180	.192	.199	.132	.130	.122			
Sulfates	.195	.090	.110	.107	.116	.122					
Carbonates	.003	.004	.005	.006	.005	.005	Large trees				
Chlorids	.009	.009	.009	.009	.009	.009					
Totals	.208	.104	.124	.122	.130	.136					
Sulfates	.168	.227	.116	.122		.163					
Carbonates	.009	.009	.006	.005		.002	Large trees				
Chlorids	.009	.009	.014	.028		.009					
Totals	.186	.245	.136	.155		.174					

A spot of maximum intensity is seen near the center of the plot where the percentage is .63 as an average of the four-foot column of soil, but thence in all directions thé percentage is less and the alkali diminishes with great irregularity out to the edges of the tract. The outlines of each area of intensity are also peculiarly curved.

The table and the diagram illustrate very forcibly the following facts,

often brought out with emphasis in this and former publications of this station:

1. That the distribution of alkali and of its salts in any plot is very irregular.

2. That great differences both in quality and in amount exist at distances of but a few feet or even less.

3. That a plant may live and grow in one part of an alkali spot and yet be killed by stronger alkali if planted but a few feet distant.

4. That an analysis giving the composition of the soil at one point of an alkali spot may fail utterly to represent the amount of alkali of other

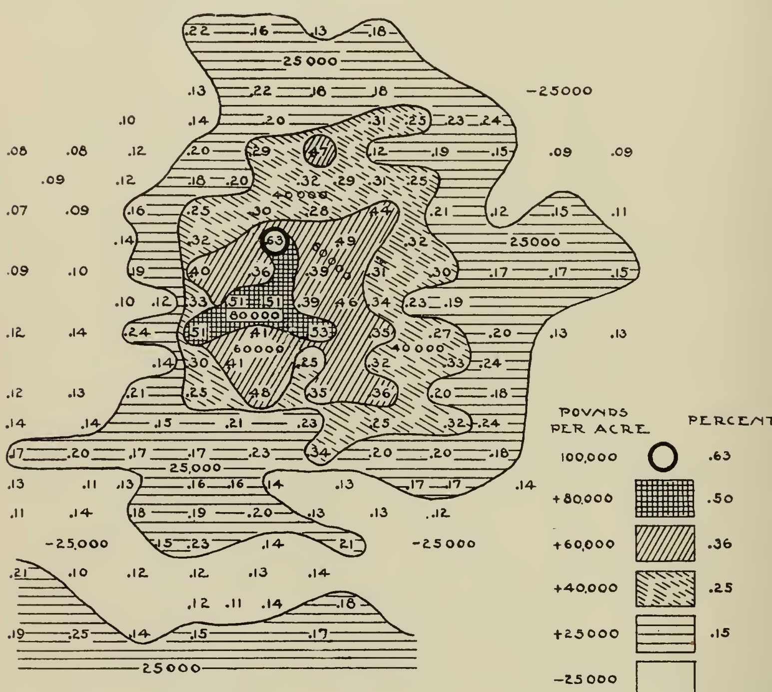

FIG. 1.—Diagram showing the distribution and intensity of alkali in the Eucalyptus plot; Tulare Station.

portions, and can not therefore be relied on when the question of treatment or crop production is to be considered.

5. That it is a grave mistake to outline large regions on a map as having each a definite percentage of alkali, for such regions mostly contain large tracts of land practically free from alkali which might thus be popularly regarded as unsuitable for crop production.

6. That the examination of an alkali spot downward is important in order to ascertain whether the alkali extends to great depths as in some parts of California, or to not more than three or four feet as is usually the case.

The area of strong alkali being limited it was determined to make plantings of but few of the more important varieties grown in this State, and we chose the *crebra, corynocalyx, cornuta, globulus, rudis, rostrata,* and *tereticornis,* small seedlings of which were obtained from the Fancher Creek nurseries at Fresno. These were planted by the foreman of the Tulare Station at distances of six feet in rows which were ten feet apart, and received two irrigations during the season. These were not planted in the rows from which soils had been taken for the original examination, but between them, and it therefore became necessary to take other samples of soil very close to the seedlings to ascertain true alkali conditions around the roots at the end of the season when the effect of the alkali was to be noted.

It was not thought necessary to examine the soil of each and all of the seedlings, and only typical ones of each of the species were analyzed, the results being given in the special discussion.

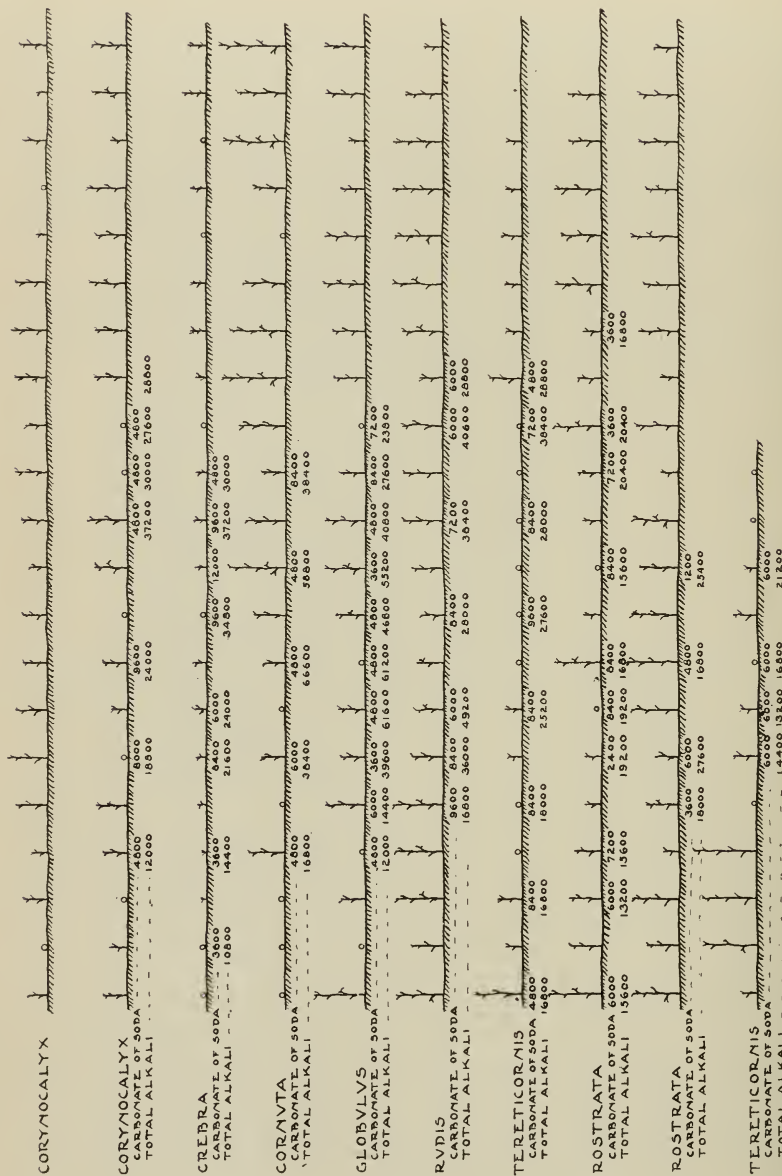

FIG. 2.—Diagram showing relative heights of seedlings and amounts of alkali near certain plants in the test plot, at the end of the first season; Tulare Station.

EFFECT OF ALKALI SALTS UPON VARIOUS SPECIES OF EUCALYPTS.

At the end of the first season, the condition and height of each plant in each species was ascertained and from these a chart (No. 2) prepared showing the relative heights; the amount of carbonate of soda and that of total alkali, given in pounds per acre in a depth of three feet very near certain seedlings, is also shown on the chart, the sulfates and chlorids being omitted as they do not seem to have produced any injurious effects.

The total number of seedlings planted was 244, and thirty-nine of these or about sixteen per cent died, presumably from the effects of alkali. A close examination, however, showed that the greater number were dwarfed or otherwise injured in comparatively small percentages of alkali salts, and that the injury was due doubtless to a combination of hurtful conditions rather than to alkali alone. The result emphasizes the importance of either eliminating from the soil all of such conditions or of not attempting to grow good trees on such poor land. The following table presents a general statement of the number of seedlings of each species that during the first season reached heights of 48 inches, from 36 to 48, from 24 to 36, from 12 to 24, and less than 12 inches and the number that died:

	Number planted.	Number within different heights.					Dead.	
		48 inches.	36-48.	24-36.	12-24.	1-12.	Number.	Per cent.
E. cornuta	27	2	5	10	3	----------	7	25.9
E. corynocalyx	54	2	3	22	19	1	7	11.0
E. crebra	25	----------	----------	----------	8	11	6	24.0
E. globulus	28	----------	----------	15	8	1	4	14.3
E. rostrata	54	2	10	17	22	----------	3	5.6
E. rudis	25	----------	8	12	5	----------	----------	----------
E. tereticornis	31	1	2	2	12	2	12	38.7

Eucalyptus tereticornis suffered more than other species, 38.7 per cent of its seedlings having died though planted in a soil containing less alkali than some of the others; the rudis suffered least of all, none of its seedlings having died. The *rostrata* lost but 5.6 per cent of its large number of seedlings.

In the following pages we give the results of the investigations thus far obtained, the amount of alkali salts under the respective trees or plants and a discussion of each of the several species tested, and we have endeavored to draw from the mass of figures some conclusions as to the tolerance of alkali salts on the part of the Eucalyptus.

EFFECT OF ALKALI SALTS UPON EUCALYPTUS CORYNOCALYX.

Investigations with *Eucalyptus corynocalyx* were chiefly made in the special alkali plot of the Tulare Experiment Station, where 54 seedlings were planted in two rows at distances of six feet, the rows being ten feet apart. Some of the trees were in strong alkali but the greater number, at either end of the rows, were planted in soils containing comparatively small amounts of the salts.

The maximum height reached by the seedlings in the first year was only 30 inches, in a soil with but little alkali and also in one containing .31 per cent of salts. Seven of the trees died, several of them from other causes than alkali; one reached a height of only 8 inches, nineteen from 12 to 24 inches, and twenty-five above that height, two of the latter being 48 inches.

In other parts of the State Mr. Johnson found but two trees that could be identified as *corynocalyx;* one near Hanford was growing in a soil that had only saltgrass on it before being brought into cultivation. It was three years old, 25 feet high, and looked thrifty though there was some yellowing of the leaves. The tree from near Fresno was two years old and 3 feet tall, and had had good care, though showing considerable effect of the alkali. It stood in a small tract where grapevines had failed to grow. The tips of its branches and leaves were reddish, and the tree rather stunted; hardpan underlaid the surface at about 4 feet.

E. CORYNOCALYX IN ALKALI SOIL.

Tree No.	Height, inches.	Age, years.	Condition.	Percentage in soil.				Pounds per acre in 3 feet.			
				Sulfates.	Carbonates.	Chlorids.	Total.	Sulfate of soda.	Carbonate of soda.	Chlorid of sodium.	Total salts.
			Tulare Station, 3 foot depth.								
11	30	----	Two lowest leaves red; others good	.25	.04	.02	.31	30,000	4,800	2,400	37,200
14	24	----	Two lowest leaves red; others good	.17	.04	.03	.24	20,400	4,800	3,600	28,800
4	18	----	Leaves of lower half spotted and dying	.05	.04	.01	.10	6,000	4,800	1,200	12,000
8	18	----	Lower leaves affected	.11	.08	.01	.20	13,200	9,600	1,200	24,000
6	6	----	Dead	.08	.05	.01	.14	9,600	8,000	1,200	18,800
12	8	----	Dead	.20	.04	.01	.25	24,000	4,800	1,200	30,000
13	8	----	Dead	.17	.04	.02	.23	20,400	4,800	2,400	27,600
	Ft.		*Other Localities, 4 feet deep.*								
---	25	3	Hanford, some yellow leaves	.08	.07	.01	.16	12,800	11,200	1,600	25,600
---	3	2	Fresno, stunted	.05	.02	.01	.08	8,000	3,200	1,600	12,800

A glance at the table will show that the sulfates have had but little to do with the injury to the young trees, as the greatest height reached was in a soil with the maximum of .25 per cent of sulfates (30,000 pounds) in three feet depth per acre.

The results with the young seedlings at Tulare were not at all satisfactory, for they attained their greatest height in the highest amount of sulfates and of common salt and in the same amount of carbonate of soda that occurs in the soil in which the seedling died. The *corynocalyx* will clearly withstand the effects of as much as .04 per cent of either common salt or carbonate, the equivalent of 4,800 pounds per acre in 3 feet, and is dwarfed by a larger amount if allowed to remain around the roots. It grew only 18 inches high the first year in presence of .08 per cent of carbonate of soda; this is equivalent to about 9,600 pounds per acre in three feet depth. The lower leaves showed the effect of the alkali. Much depends upon the distribution of the several salts in the soil column, for in this case an examination showed that the carbonate of soda and the sulfates were confined chiefly to the third foot, while the common salt was in largest amount in the upper two feet.

The older trees in other localities, as shown in the table, have yielded some interesting results from the examination of their soils. The samples of soil were taken to depths of four feet, and we find that the two-year-old tree at Fresno with a height of three feet was stunted in presence of only .02 per cent of carbonate of soda in the four feet, or an equivalent of but 3,200 pounds per acre, while a three-year-old tree at Hanford was 25 feet high in presence of .07 per cent of carbonate of soda. The conclusion is plain, that the young *corynocalyx* will not withstand a large amount of carbonate of soda unless the alkali be kept away from the tender roots by thorough irrigation methods; and that after it gets a good start and the roots are developed downward, the amount of carbonate of soda may be quite large without detriment to the tree.

Observations in 1910.—After the station was abandoned no attention was given to the trees, and a visit to the plot showed that ten more of the *corynocalyx* had died, six were still barely living while nineteen others (chiefly at the ends of the rows where the alkali was less) had increased in height. The greatest increase in growth was 28 inches at the extreme eastern end, and 18 inches on the west. Tree No. 4 in a soil with .04 per cent of carbonate of soda had grown 12 inches, while Nos. 11 and 14, with the same amount of carbonate, had died.

EFFECT OF ALKALI ON EUCALYPTUS CREBRA.

Eucalyptus crebra seems to be one of the slowest-growing of the Eucalyptus species, for in the Tulare Station plot, where 25 seedlings about 2 inches high were planted, the maximum height reached the first year in good soil and under favorable conditions was but 18 inches. Six of the seedlings died quickly, three made no additional growth

though keeping alive, four reached a height of six inches, four a height of 6 to 12 inches while but five grew from 12 to 18 inches high. The young seedlings are evidently very sensitive to the effects of alkali salts, for throughout nearly the entire row the leaves and the plants themselves were either dead, dying or dwarfed.

Trees Nos. 2 and 4, growing in two feet of sand overlying a clay which was full of young rootlets were but two inches high though green; No. 6 appeared healthy, had no dead leaves but was only 6 inches high; No. 7 was growing in a better soil, but its lower leaves were dead, and others becoming reddish. No. 9, two inches in height was entirely dead; No. 11 with alkali salts upon the surface of the soil around it grew 10 inches high, but the alkali had killed the lower leaves. No. 10, also surrounded by black alkali, was dying, both leaves and tips of limbs being affected; No. 12, 6 inches high was living but the leaves and tips of limbs were dying back.

These seedlings just described were selected as probably giving best results and their soil was taken to depths of three feet for alkali examination. The results are given below.

E. CREBRA IN ALKALI SOIL.

Tree No.	Height, inches.	Condition.	Percentage in soil.				Pounds per acre, 3 feet.			
			Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total alkali.
2	2	Healthy, but no growth	.05	.03	.01	.09	6,000	3,600	1,200	10,800
4	2	Healthy, but no growth	.04	.03	.05	.12	4,800	3,600	6,000	14,400
6	6	Healthy, little growth	.05	.07	.06	.18	6,000	8,400	7,200	21,600
12	6	Leaves curling	.19	.04	.02	.25	22,800	4,800	2,400	30,000
11	10	Lower leaves dead	.22	.08	.01	.31	26,400	9,600	1,200	37,200
7	4	Dying, lower leaves dead	.14	.05	.01	.20	16,800	6,000	1,200	24,000
10	6	Dying, lower leaves dead	.18	.10	.01	.29	21,600	12,000	1,200	34,800
9	2	Dead	.15	.08	.09	.32	18,000	9,600	7,200	34,800

Eucalyptus crebra clearly can not withstand a large amount of alkali if we are to judge from the above observations; for the young seedlings began to die in presence of .20 per cent of combined salts (equivalent to 24,000 pounds per acre in a depth of three feet) even when the carbonate of soda was less than where the tree was healthy. The greatest percentage of carbonate of soda in the soil of a healthy seedling was .07, corresponding to about 8,400 pounds per acre in three feet; this was combined with an equal amount of common salt.

In a row of eucalypts planted many years ago just outside of the south fence of the station tract there is a *crebra* having a height of 75 feet, which appears very healthy though growing in .11 per cent of alkali in four feet depth, which is equivalent to about 17,600 pounds per

acre; there is present only .02 per cent of carbonate of soda (3,200 pounds per acre) and the same amount of common salt. This is nearly the same amount of carbonate of soda and total salts that were found with the healthy seedlings having only two inches growth; evidently the failure of the latter to grow was due to other causes than alkali, or conditions were more favorable for the large tree when it was young.

Observations in 1910.—A year after the above observations and the abandonment of the station, further observations on the *crebra* showed that eleven more of the trees had died, chiefly in the region of strong alkali that was covered by a dense growth of alkali weed. Only three trees had shown any increased growth, one of which, No. 6, which was in .07 per cent of carbonate of soda, had grown but 6 inches in the past year. Others that had less of the carbonate had died.

The *crebra* is certainly not suited to alkali conditions.

EFFECT OF ALKALI ON EUCALYPTUS CORNUTA.

Cornuta was one of the species of eucalypts chosen for the Tulare Station plot and 27 young seedlings were set out early in the year and given the same irrigation and attention received by other species. In a good soil the growth was as great during the first year as made by any other species in this plot, the height reached being 48 inches, but only two of the trees reached this. Five other trees grew from 36 to 48 inches, ten from 24 to 36 inches, and three from 18 to 24 inches; seven of the trees had died either soon after planting or after reaching a foot or more in height.

The soils of only six of the trees that were apparently affected by alkali salts were taken for examination. Tree No. 2 had been planted in a sandy soil with hardpan at two feet and was evidently killed by lack of moisture, as the amount of alkali was very small. No. 4 was green but the tips of the leaves were beginning to turn yellow; its soil was sandy to two feet depth and underlaid by a clayey soil. No. 6 had grown to a height of two feet in a soil having hardpan at four feet, but had finally succumbed to the alkali. No. 8 in a soil similar to that of No. 4 was more severely affected by the alkali, some of the leaves beginning to die. No. 10 in a soil with .5 per cent of alkali salts and with a moist clayey subsoil at three feet showed signs of injury as some of the leaves were dying; and No. 12 in a soil similar to that of No. 10 but with less total salts and more carbonate of soda also showed the effect of the latter by the dying of the lower leaves.

The results of the examination are given in the following table:

E. CORNUTA IN ALKALI SOIL.

Tree No.	Height, inches.	Condition.	Percentage in soil.				Pounds per acre, 3 feet.			
			Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
10	42	A few leaves dying	.43	.04	.02	.49	51,600	4,800	2,400	58,800
4	24	Tips of leaves changing	.09	.04	.01	.14	10,800	4,800	1,200	16,800
12	20	Lower leaves dying	.24	.07	.01	.32	28,800	8,400	1,200	38,400
8	18	Leaves dying	.53	.04	.06	.63	60,600	4,800	1,200	66,600
6	24	Dead	.26	.05	.01	.32	31,200	6,000	1,200	38,400

From this table it would appear that the *cornuta* is quite sensitive to the presence of alkali salts in its soil, if the amount be as much or more than .5 per cent of total salts.

It reached its maximum height of 48 inches in .15 per cent of alkali, and 42 inches in as much as .49 per cent, but in the latter the leaves had begun to die, evidently from the effect of the alkali. The carbonate of soda seems to be controlling cause of injury to the trees for there was but .01 per cent (1,200 pounds per acre 3 feet depth) where the tree was not affected and .04 per cent where the leaves were dying though the tree was 42 inches high. In another spot a tree had grown 45 inches without apparent injury in presence of .17 per cent of total alkali and .01 per cent of carbonate of soda.

We would then place the limits of tolerance on the part of *cornuta* at about .5 per cent of total alkali salts, provided there was not more than .03 per cent of carbonate of soda present.

Observations in 1910.—A visit to the Tulare Station after its abandonment showed that all of the twenty *cornuta* trees were dead along the row through the dense patch of weeds to the east end, where a few trees had survived and had made additional growth of a foot or more in weak alkali soil. The trees were killed by the alkali and the alkali weeds.

The *cornuta* is evidently not an alkali-resistant eucalypt.

EFFECT OF ALKALI ON EUCALYPTUS GLOBULUS.

There were only twenty-eight seedlings of *Eucalyptus globulus* put in a row across the alkali plot of the Tulare Station, a few being in that part which contained 40,000 to 60,000 pounds (.35 to .50 per cent) of the salts in a depth of 3 feet per acre. The irregular distribution of the salts is well shown in diagram No. 1; No. 5 having a total of .12 per cent, while No. 6, six feet distant, has .35 per cent, and No. 7 at a distance of six feet from No. 6 has more than .50 per cent of alkali in three feet depth.

The greatest height attained in one season after planting was 34 inches, by two of the seedlings, in a soil having but little alkali. Six of the seedlings grew to 30 inches; seven 24 inches; six to 18 inches, while the others fell below this height, four dying completely. A few were selected for alkali examination, the samples of soil being taken to three feet in depth.

The seedlings were set out in the spring and it is more than likely that at that time the surface soil was quite free from alkali because of the winter and spring rains, thus enabling the roots to secure a foothold before the subsequent rise of alkali to the roots. In the fall, at the time the soil samples were taken for examination, a detailed analysis showed that the alkali was concentrated in the upper two feet where the young seedling roots were held subject to its influence. It was also found that while the sulfates and the common salt were each chiefly in the upper two feet, the carbonate of soda, on the contrary, was mainly held in the first foot. The results of analysis are shown in the following table:

E. GLOBULUS IN ALKALI SOIL.

Tree No.	Height, inches.	Condition.	Percentage in soil.				Pounds per acre, 3 feet.			
			Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
10	30	Leaves touched	.41	.03	.02	.46	49.200	3,600	2,400	55,200
11	30	Leaves touched	.29	.04	.01	.34	34,800	4,800	1,200	40,800
12	18	Leaves dying	.14	.07	.02	.23	16,800	8,400	2,400	27,600
6	18	Leaves dying	.29	.03	.01	.33	34,800	3,600	1,200	39,600
7	18	Dead	.46	.04	.01	.51	55,200	4,800	1,200	61,200
5	18	Leaves turning	.06	.05	.01	.12	7,200	6,000	1,200	14,400
9	12	Leaves dying	.33	.04	.02	.39	39,600	4,800	2,400	46,800
4	3	Dead	.05	.04	.01	.10	6,000	4,800	1,200	12,000
8	10	Dead	.46	.04	.01	.51	55,200	4,800	1,200	61,200
13	8	Dead	.12	.06	.01	.19	14,400	7,200	1,200	23,800

A study of the alkali figures and the condition of the trees point plainly to the fact that it is a mistake to base the tolerance of alkali by a plant alone upon the total amount present in a certain depth of soil, but that the amounts of individual salts must be taken into account. Thus, we find the tree growing to its maximum height of 30 inches in a spot where there was .46 per cent of total alkali (55,200 pounds per acre in 3 feet), while it was dwarfed in much smaller amounts because of the presence of more carbonate of soda in the upper two feet. In another spot the growth was but 18 inches in presence of .51 per cent of alkali, but the tree had died, and probably the slow growth as well as the death of the seedling was due to the larger amount of carbonate of soda as well as of the total alkali.

That the sulfate of soda has but little injurious effect on any plant, except in very large amounts, has been shown in other publications of

this station, and is here well illustrated in tree No. 10 which grew to a height of 30 inches in the presence of .41 per cent of sulfates, or the equivalent of about 50,000 pounds per acre in a depth of 3 feet.

The carbonate of soda was the most hurtful of the alkali salts, and the seedlings seem to show in their leaves that they feel the effect of .04 per cent, though the plant No. 11 reached its maximum growth of 30 inches in a soil containing that percentage. Where the percentage of carbonate of soda was more than .04 the seedlings were either dwarfed in growth or dead. It seems, then, that the limit of tolerance of the *E. globulus* for carbonate of soda may be placed at .04 per cent or its equivalent of about 5,000 pounds per acre in a depth of three feet.

The tree is not as susceptible to common salt as to carbonate of soda, and the amounts found in the row of trees are hardly worthy of consideration, the highest amount being but .02 per cent, or 2,400 pounds in 3 feet depth per acre, and in this it reached nearly its greatest growth.

It is evident that other causes than alkali alone have caused the death or dwarfing of many of the seedlings. In fact, Nos. 4 and 13, which were killed, and No. 5, which was dwarfed, were in soils holding less total salts, as well as less of each salt than No. 12 which grew to a height of 18 inches.

Observations in 1910.—Observations made a year later on the condition of the young *globulus* at the station showed that every young tree from Nos. 4 to 20, had died either from lack of water, from the effect of alkali, or because of the dense mass of alkali weed that had been allowed to grow after the station was abandoned. All of the plants, the analyses of whose soils are given in the tables, were dead and only outside of the weed patch and almost wholly on the east, where there was but little alkali, had the trees made additional growth, the maximum increase being about four feet.

Young E. globulus at Buena Park, Orange County.—Buena Park is located in the region of alluvial lands that lie south of Los Angeles. In this is a young grove of *E. globulus* on the east side of the railroad, two miles north of Buena Park, which was planted three years before this examination was made. A large alkali spot occurs in the grove, and though planted and treated as the rest, the young trees within its area were killed by the excessive alkali which covers the ground in summer with a white crust. The alkali spot is irregular in outline and along its border are trees that have been more or less dwarfed by the alkali and seemed to afford good examples for study.

The accompanying photographs show the conditions prevailing in this field; Fig. 3 is a view of the thick crust of alkali salts, cut into by the wheel of the vehicle. The soil had been thrown up into ridges for irrigation and the planting of the eucalypts; the tops of the ridges show thicker alkali than in the swales where it is weaker and permits of the

growth of alkali weeds. The trees that were planted all died, except along the border, as shown in the photo, and there those in front were lower in height than those in the rear though of the same age, evidently the effect of the stronger alkali. The other photograph is a nearer view of the tall trees with smaller ones on the right, which in turn give way to only alkali weeds and grass and finally to only alkali salts, as shown in the other photograph. Soils Nos. 1, 2 and 9 are from the locality shown in Fig. 4, while the others are from along the border of the trees shown in Fig. 3.

Certain of the young trees were chosen that were seemingly affected differently by different amounts of the alkali and samples of their soil were taken within a few inches of the tree, and to a depth of 4 feet, and submitted to chemical analysis. The results are shown in the following table:

E. GLOBULUS IN ALKALI SOIL NEAR BUENA PARK, LOS ANGELES COUNTY.

Soil No.	Height, feet	Condition.	Percentage in soil.				Pounds per acre, 4 feet.			
			Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
1	22	4½ inches in diameter	.21	.02	.03	.26	33,600	3,200	4,800	41,600
2	10	1¾ inches in diameter	.11	.04	.01	.16	17,600	6,400	1,600	25,600
3	10	1¾ inches in diameter	.17	.02	.03	.22	27,200	3,200	4,800	35,200
4	3	Healthy	.18	.02	.05	.25	28,800	3,200	8,000	40,000
5	6	Lower branches dead	.22	.06	.04	.32	35,200	9,600	6,400	51,200
6	7	Dying	.33	.05	.10	.48	52,800	8,000	16,000	76,800
7	8	Dead	.36	.02	.12	.50	57,600	3,200	19,200	80,000
8	----	Salt grass only	.19	.05	.05	.29	30,400	8,000	8,000	46,400
9	----	Salt grass and weeds	.27	.09	.03	.39	43,200	14,400	4,800	62,400
10	----	Salt grass only	.49	.02	.12	.73	78,400	3,200	19,200	100,800
11	----	Nothing growing	.53	.12	.14	.84	92,800	19,200	22,400	134,400

In this grove we found a tree, No. 1, 22 feet in height growing where there was no indication of alkali, as the ground around it was covered with grass, and yet the examination showed the presence of .26 per cent (nearly 42,000 pounds per acre) of total salts in 4 feet depth. The tree was in splendid condition, full foliage and with a trunk having a diameter of four and one half inches. There was but .02 per cent of carbonate of soda in the soil. A tree, No. 2, near this, having a height of but ten feet, though of the same age, had twice the amount of carbonate of soda, .04 per cent (6,400 pounds per acre) in four feet depth. The tree was healthy and had a diameter of one and three fourths inches. The diminished growth is probably due to the larger amount of carbonate of soda, for in a soil having a still greater amount, .06 per cent (9,600 pounds per acre), a tree, No. 5, was growing with a height of but six feet and some of the lower branches were dead. A few feet from No. 2 the alkali was so strong, No. 9, that only salt grass and alkali weeds would grow in it. Where the trees Nos. 6 and 7 were dead or dying

FIG. 3.—Alkali field with Eucalyptus globulus on border.

FIG. 4.—Eucalyptus globulus on border of alkali field. Alkali weeds in foreground.

the cause seemed to be the great excess of alkali salts, which covered the ground with a white incrustation and prevented proper aeration; that the common salt alone was not responsible is shown by the fact that tall trees have been found in other places growing well in as much as .50 per cent or an equivalent of about 40,000 pounds per acre in two feet depth.

It will be seen from the table that where there was as much as .48 per cent of alkali salts, comprising very high per cents of carbonate or common salt the *E. globulus* was dying when 7 feet high; and that where there was as much as .09 per cent of carbonate of soda (14,400 pounds per acre), only salt grass and alkali weeds will grow; that salt grass alone grew in presence of .49 per cent of sulfates and .12 per cent of common salt; and that nothing at all was able to live in .84 per cent of total salts (134,400 pounds per acre) in which there was .12 per cent of carbonate and .14 per cent of common salt.

Groves of E. globulus in other Localities.—A grove of *E. globulus* near Centralia schoolhouse, a few miles southwest of Buena Park, was planted in 1909 in a strip of alkali land and the trees showed varying effects of the alkali salts. The grove was visited by Mr. F. E. Johnson and soils taken from near a number of the trees and examined. The greatest height of the unaffected trees was 3 feet and the one of this height selected was growing in 19,200 pounds of salts, the greater part of which was sulfates. Other trees more or less affected are given in the table below.

In the region around Fresno were found many old trees growing in alkali soils, some of which were examined by Mr. Johnson; No. 5, about twenty-five years old, tall and having a diameter of about 15 inches, showed no indication of injury from the alkali; No. 6, twenty-five years old, thirty-five feet tall and having a diameter of 12 inches was growing in a locality whose soils seemed to be strongly charged with alkali salts and underlaid at a depth of about 3 feet by hardpan. It was, however, but slightly affected by the alkali although there was a large (.05 per cent) amount of carbonate of soda. No. 7, eight years old, was severely affected by the strong alkali about its roots, was sickly in appearance and many of its leaves were reddish in color; and No. 8, six years old, growing in a soil having .14 per cent (22,400 pounds per acre 4 feet) of carbonate of soda was stunted in growth though otherwise showing no effects of the alkali. This is the largest amount of carbonate of soda found in the soil of any eucalypt (except an unidentified species) that had attained any considerable growth. Unfortunately, the early treatment of the tree is not known, but it was doubtless well cared for and the alkali kept from the young roots until they had passed beyond the danger zone.

The results of the soil examination are given in the following table:

E. GLOBULUS IN ALKALI SOILS.

Tree No.	Age, years.	Height.	Effect of alkali.	Percentage in soil.				Pounds per acre, 4 feet.			
				Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total alkali.
			Centralia Schoolhouse.								
1	1	36 in.	None	.08	.02	.02	.12	12,800	3,200	3,200	19,200
2	1	30 in.	Slight	.14	.01	.03	.18	22,400	1,600	4,800	28,800
3	1	24 in.	Moderate	.15	.01	.02	.18	24,000	1,600	3,200	28,800
4	1	14 in.	Severe	.20	.05	.05	.30	32,000	8,000	8,000	48,000
			Near Fresno.								
5	25	Tall	None	.50	.05	.03	.58	80,000	8,000	4,800	92,800
6	25	35 ft.	Slight	.02	.05	.05	.12	3,200	8,000	8,000	19,200
7	8	-------	Sickly	.08	.07	.04	.19	12,800	11,200	6,400	30,400
8	6	-------	Stunted	.11	.14	.03	.28	17,600	22,400	4,800	44,800

In the above table there is seen to be a regular gradation in height of the young trees near Centralia schoolhouse from 30 inches to 14 inches following the increasing amounts of alkali salts from .12 to .30 per cent (19,000 to 48,000 pounds per acre) in 4 feet depth, and the conclusion is inevitable that this increase has something to do with the dwarfing or retarding of the growth. It is clear that .02 per cent of carbonate of soda in 4 feet depth per acre has no effect on the young tree, while it would seem that the tree does severely feel the presence of a little more than twice that amount.

When, however, we turn to the older trees from near Fresno, we find that they are not at all affected by these amounts, and are growing well in as much as .07 per cent (11,200 pounds per acre) each of the carbonate and chlorid in four feet depth, though stunted in the presence of .14 per cent of carbonate of soda. Evidently the delicate roots have managed to escape contact with this large amount of carbonate of soda, and had passed beyond the danger point before the alkali returned to the surface. The sulfates even to the extent of .5 per cent or 80,000 pounds per acre 4 feet depth also seem not to be hurtful to the tree.

This table is very instructive and from it we must conclude that the tender bark of the roots of the *globulus* when very young are very susceptible to corrosion and injury by as much as .05 per cent or 8,000 pounds of carbonate of soda in four feet depth; but if, by irrigation, the alkali can be carried down to several feet below the surface and kept there by proper cultivation and mulching of the surface soil until the tree is able to send the roots deeply and far out laterally beyond the alkali, and has time to envelope the surface roots with a thick bark not susceptible to the alkali, there may be present double the amount of alkali without injury to the tree.

The accompanying photograph Fig. 5 is of a *globulus,* 75 feet high, growing in an alkali soil west of Wasco, Kern County. When young, the tree had had thorough irrigation from an artesian well on the place which had carried the greater part of the alkali salts to a depth below five feet, as was shown by an examination of a seven-foot column of the

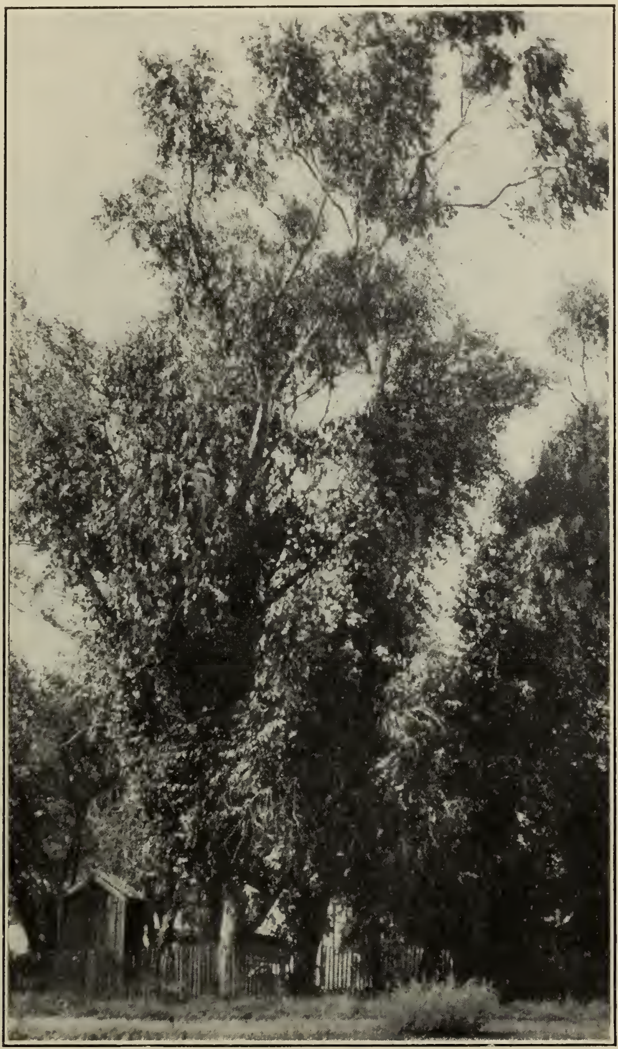

Fig. 5.—Eucalyptus globulus in alkali soil. Effect of irrigation.

soil taken a few years ago; at that time there was .05 per cent of alkali in the upper four feet and .14 per cent in the lower three feet. The sulfates and chlorid were chiefly in the lower part of the column while the carbonate of soda was about evenly distributed throughout.

E. globulus in Salt Marshes and Tule Islands.—The swamp and tule lands, that mark the junction of the two great rivers of the Sacramento and San Joaquin lying in the great valley and covering approximately 1,000 square miles, are largely at or near tide water or sea level, and intersected irregularly by sloughs which divide the region into many "islands," whose lands have to be protected against overflow from the rivers by levees before being capable of safe cultivation and crop production. The water of these sloughs, as well as of the rivers for many miles upstream, are more or less mixed with the salty tide water of the bay, and by percolation the salt has been carried into the lands of the islands, as well as rising into the levees that surround them.

Along the levees of a number of these islands there were planted many years ago long rows of eucalypts, mostly of the *globulus* variety, to serve as windbreaks. These trees have grown to heights of from 40 to 60 or more feet although some of their roots are bathed constantly by salt water, and others are living in a soil of but two or three feet above water level and carrying a high percentage of salts.

Similarly, the salt marshes that border the bay of San Francisco in Marin County, known as the Novato Meadows, have many trees growing in the shallow and more or less salty soil.

Samples of soil from very near some of these trees of the Novato Meadows, and from one of the "islands" were taken down to the water level (two feet), and subjected to analysis with the following results:

E. globulus in Alkali Soils of Marsh and Tule Lands.

	Percentages.			Pounds per acre, 2 feet.		
	Sulfates.	Chlorids.	Total.	Sulfates.	Chlorids.	Total.
Tule Island	.69	.56	1.25	55,000	44,800	99,800
Novato Meadows	.14	.42	.56	11,200	33,600	44,800

These are very large amounts of each salt and plainly show that the *globulus* is not sensitive to the presence of either sulfate of soda or common salt in its soils. There was no carbonate of soda in soils examined.

We find, then, that *Eucalyptus globulus,* after passing the young stage of growth and getting its roots deeply in the soil, will withstand a large amount of alkali salts, provided the carbonate of soda does not exceed .05 per cent.

EFFECT OF ALKALI ON E. RUDIS.

In the alkali plot of the Tulare Experiment Station there were planted 25 young seedlings of *E. rudis,* eight of which reached a maximum height of 36 inches during the first season after planting both in a soil having but little alkali and in the spot having as much as .14 per cent or

nearly 17,000 pounds per acre in 3 feet depth, of which nearly one half was carbonate of soda. Twelve others of the seedlings grew from 24 inches to 36 inches, and the others from 15 to 24 inches. None of the young trees were killed by the alkali, though some were dwarfed and failed to reach the height they should have done.

E. RUDIS IN ALKALI SOILS: TULARE STATION.

Tree No.	Height, inches.	Condition.	Percentage in soil.				Pounds per acre, 3 feet.			
			Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
5	36	Good	.05	.08	.01	.14	6,000	9,600	1,200	16,800
13	27	Leaves affected	.26	.05	.02	.33	31,200	6,000	2,400	40,600
6	24	Good	.21	.07	.02	.30	25,200	8,400	2,400	36,000
11	20	Good	.24	.06	.02	.32	28,800	7,200	2,400	38,400
7	18	Good	.35	.05	.01	.41	42,000	6,000	1,200	49,200
14	18	Good	.16	.05	.03	.24	19,200	6,000	3,600	28,800
9	15	Good	.17	.07	.01	.25	20,400	8,400	1,200	28,000

Unfortunately for the experiment, the row of young seedlings did not cross the part of the plot having the strongest alkali, and hence were not subjected to as severe a test as the *cornuta* and *globulus*, where the maximum amount of alkali salts was .51 per cent or about 61,000 pounds per acre in 3 feet depth.

The maximum amount of total salts in the *rudis* test was .41 per cent or about 49,200 pounds per acre, and in this the seedling reached a height of 18 inches. The lowest height of any tree was 15 inches and this was in the presence of only .25 per cent or 28,000 pounds per acre, but in this there was .07 per cent (8,000 pounds per acre) of carbonate of soda. That other conditions than alkali alone had affected the *rudis* was shown in seedlings Nos. 7 and 14, each with a height of 18 inches and in whose soils there was respectively .41 and .24 per cent of alkali, and in which the carbonate and the chlorid were almost the same in amount. In other places also where there was but little alkali the growth was very small.

Conditions in 1910.—Observations made on the *rudis*, a year later than above and after the station had been abandoned leaving the plot entirely neglected, showed that eleven of the young trees had died, comprising those in the center of the row and where a dense and tall growth of alkali weed had appeared. However, seven of the trees in this weed patch had increased from 24 to 36 inches in height and two more were holding their own and were the only eucalypts living within this area, with the exception of one each of *tereticornis* and *crebra* which were in the edges of the weeds. The killing out of the trees was due doubtless to the lack of water and to the presence of the weeds, as

the amount of carbonate of soda present in their soils was less than in No. 5, which still lived in .08 per cent.

Other Localities.—In the investigations made by Mr. Johnson in other parts of the State, samples of alkali soil were taken from twenty-five or more of the *E. rudis* and submitted to analysis. The greater number of these had less alkali than could produce unfavorable effects upon the tree and all but nine have been omitted from the table.

The first tree given in the following table was from near Fresno; it was three years old, 8 feet high, and well proportioned and showed no bad effect of the .20 per cent of alkali in its soil. No. 2 from Kingsburg also was in good health, though growing in a soil with .25 per cent of alkali salts, and had received no cultivation. No. 3 from Hanford, 5 feet high, had received fairly good cultivation and was not suffering from the .28 per cent of alkali in its soil, which was equal to nearly 50,000 pounds per acre in 4 feet depth. A detailed analysis of each foot showed that the carbonate of soda was distributed rather evenly through the four-foot column, that three fifths of the sulfates and of the chlorids also were in the first foot and one fifth in the second foot. The water level was at five feet. No. 4 from Kingsburg had received no cultivation and was growing in hard ground covered with weeds and salt grass. A gravelly hardpan occurred at two feet below the surface but the roots of the tree had passed through it into the soil below. Notwithstanding these drawbacks and the presence of .24 per cent of alkali salts, the tree was not suffering. No. 5 from Hanford, three years old and 15 feet high, was growing in a soil covered with a powdery coating of alkali and holding .20 per cent of alkali. Grapes had all died in this soil, but the *rudis* showed no marked ill effect except in smaller leaves and red spots. No. 6 from the same place had been planted in a barrel filled with good soil and covered over with manure and sunk into the alkali-crusted soil; the seedling reached a height of 6 feet in two years, but the alkali became diffused into the soil of the barrel and the tree began to show some bad effects. No. 7 from Fresno had apparently died down and again grown up from a sucker; it looked very badly though 5 feet high, many of the tips of the shoots being dead and some of the leaves mottled red, though the amount of alkali was not large. No 8 from near Fresno was 6 feet tall, with but few branches and some of the leaves near the ends of the branches being mottled red. No. 9 from Hanford, one year old standing in strong alkali soil, crusted over with alkali was alive but not growing.

E. RUDIS IN ALKALI SOILS.

Tree No.	Locality.	Age, years.	Height, feet.	Effect of alkali.	Percentage in soil.				Pounds per acre, 4 feet.			
					Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
1	Fresno	3	8	No effect	.09	.05	.06	.20	14,400	8,000	9,600	32,000
2	Kingsburg	3	----	No effect	.13	.04	.08	.25	20,800	6,400	12,800	40,000
3	Hanford	2	----	No effect	.16	.07	.05	.28	25,600	11,200	8,000	49,800
4	Kingsburg	5	----	No bad effect	.13	.04	.07	.24	20,800	6,400	11,200	38,400
5	Hanford	3	15	Leaves spotted red	.14	.05	.01	.20	22,400	8,000	1,600	32,000
6	Hanford	2	6	Leaves spotted red	.04	.08	.01	.13	6,400	12,800	1,600	10,800
7	Fresno	----	5	Mottled red leaves	.05	.04	.03	.12	8,000	6,400	4,800	19,200
8	Fresno	----	6	Mottled red leaves	.09	.07	.06	.22	14,400	11,200	9,600	35,200
9	Hanford	1	----	Alive, but not growing	.04	.09	.01	.14	6,400	14,400	1,600	22,400

There is not much to be said regarding these results, except that the *rudis* was not affected by as much as .28 per cent or 45,000 pounds of total alkali salts per acre in a depth of 4 feet, even when .07 per cent or 11,200 pounds of that was carbonate of soda and .05 per cent or 8,000 pounds was of common salt. We find, however, that when this amount of carbonate is increased to nearly .09 per cent or 15,000 pounds as at Hanford, the tree failed to grow though keeping alive.

Several of the trees with less amounts of carbonate of soda had leaves on some of the branches that were mottled with red spots. These spots have been regarded as the effect of the alkali, but this is doubtful, as we find in the Tulare experiments that very young trees, less than a year old, were not thus affected even in 9,000 pounds of carbonate of soda. A height of 6 feet in two years is very good for the *rudis* and even if the mottled leaves are thus colored by alkali the growth does not seem to be injured.

On comparing these with the results of the special test on the alkali spot at Tulare Station given above, we find that the figures of tolerance in the latter are higher.

The *E. rudis* will evidently grow well in a soil containing as much as .08 per cent of carbonate of soda, if other conditions are favorable.

EFFECT OF ALKALI SALTS UPON E. TERETICORNIS.

The only observations made upon this species of Eucalyptus were those of the special plot of the Tulare Station. In this plot there were planted thirty-one young seedlings of the *E. tereticornis* in two rows, but not across the strongest alkali, as will be seen from the chart. It was perhaps unfortunate that the test could not have made more severe along with the *globulus, rudis,* etc., for the *tereticornis* is regarded by some as being one of the best alkali-resistant eucalypts; this is, however, not borne out by the Tulare tests, for in the entire number of young trees there were but three that reached the height of from 36 to 48 inches without showing some sign of distress, as shown either in the small growth, or in the yellowing of the leaves, or in tipping them with red, a condition which seems to come from the alkali. Twelve of the thirty-one seedlings (38.7 per cent) died completely, while others had nearly succumbed at the end of the first year. Twelve were from 12 to 24 inches high and two not more than 10 inches. Twelve of the young trees were selected for the examination of the alkali content of their soil and samples of the latter were taken to depths of 3 feet. The results of the analyses are given in the following table, which is arranged from highest to lowest of tree growths:

E. TERETICORNIS IN ALKALI SOILS: TULARE STATION.

Tree No.	Height, inches	Condition of tree.	Percentage in soil.				Pounds per acre, 3 feet.			
			Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
1	24	Well branched, trunk ½ in. diameter	.09	.04	.01	.14	10,800	4,800	1,200	16,800
14	24	Two lower limbs affected	.18	.04	.02	.24	21,600	4,800	2,400	28,800
3	18	Few leaves dying	.06	.07	.01	.14	7,200	8,400	1,200	16,800
6s	18	Few lower leaves dying	.06	.05	.01	.12	7,200	6,000	1,200	14,400
7	12	Leaves spotted red	.13	.07	.01	.21	15,600	8,400	1,200	25,200
7s	12	Yellow leaves, spotted red, some dead	.05	.05	.01	.11	6,000	6,000	1,200	13,200
10s	8	Small leaves, spotted red	.12	.05	.01	.18	14,000	6,000	1,200	21,200
8s	8	Nearly dead	.08	.05	.01	.14	9,600	6,000	1,200	16,800
5	6	Dead	.07	.07	.01	.15	8,400	8,400	1,200	18,000
9	4	Dead	.13	.08	.02	.23	15,600	9,600	2,400	27,600
11	----	Dead	.17	.07	.01	.25	18,400	8,400	1,200	28,000
13	----	Dead	.22	.06	.04	.32	26,400	7,200	4,800	38,400

The maximum of total salts was .32 per cent or an average of 38,400 pounds per acre in 3 feet depth; that of carbonate of soda was .08 per cent or 9,600 pounds per acre, and that of the chlorid or common salt was .04 per cent or 4,800 pounds per acre in 3 feet depth. In the presence of each of these amounts the young tree had died, and was nearly dead in smaller amounts.

The alkali sulfates are seen in the above table to have had very little

effect on the young trees; and the common salt was not in excess in the soil of any of the trees.

The carbonate of soda appears to be the sole cause of injury from alkali, and we find that when the amount was in excess of .04 per cent or 4,800 pounds per acre in 3 feet depth the leaves began to die or turn yellow, while in larger amounts than .07 per cent or 8,400 pounds per acre the seedlings succumbed.

The maximum growth of 48 inches was reached in the presence of .03 per cent or 3,600 pounds of carbonate of soda in a total of only .16 per cent or about 19,000 pounds per acre.

The above is a poor showing for the *tereticornis* and indicates that the tree will not attain a good growth if as much as .05 per cent of carbonate of soda be allowed to remain in the upper three feet of soil.

Observations in 1910.—The abandonment of the station in 1910 caused the alkali plot to be neglected and the trees sorely tested not only by lack of irrigation and by the alkali, but by the dense growth of alkali weeds that sprang up in the central part of the plot occupied by 101 eucalypts. The *tereticornis* suffered with the rest and all of the 12 trees of the two rows in the weed patch that had escaped the first effects of alkali succumbed, with the exception of one on the extreme west, which made an additional growth of 8 feet in presence of .04 per cent of carbonate of soda in its soil. Outside of this patch two trees made increased growths of several feet but all others died.

It may be safely assumed that the *tereticornis* will attain good growth in an alkali that does not contain more than .04 per cent of carbonate of soda in a depth of three or four feet.

EFFECT OF ALKALI ON E. ROSTRATA.

Young *rostrata* seedlings were planted in the special alkali plot of the Tulare Station, but unfortunately not through the strongest part, the maximum of alkali in the two rows being but .24 per cent or 28,800 pounds per acre in 3 feet depth. The amount of carbonate of soda in a portion of the rows was, however, quite high.

The number of seedlings planted was 54 and all but three of these remained alive at the end of the first season, though many were greatly retarded in growth. The maximum height at the end of the first year was 48 inches in a good soil which had as much as .05 per cent or 6,000 pounds of carbonate of soda per acre in 3 feet depth. But two of the seedlings reached this height, ten were 36 inches, seventeen were 24 inches and twenty-two were 12 inches high.

Soils three feet deep from a number of the typical trees were exam-

ined as to alkali contents and the results are given in the following table:

E. ROSTRATA IN ALKALI SOIL: TULARE EXPERIMENT STATION.

Tree No.	Height, inches	Condition of tree.	Percentage in soil. Sulfates	Percentage in soil. Carbonates	Percentage in soil. Chlorids	Percentage in soil. Total	Pounds per acre, 3 feet. Sulfates	Pounds per acre, 3 feet. Carbonates	Pounds per acre, 3 feet. Chlorids	Pounds per acre, 3 feet. Total alkali
1	48	Good; long branches	.07	.05	.01	.13	8,400	6,000	1,200	15,600
8s	46	Good; long branches	.09	.04	.01	.14	10,800	4,800	1,200	16,800
8	36	Good; long branches	.06	.07	.01	.14	7,200	8,400	1,200	16,800
13	36	Good	.13	.03	.01	.17	15,600	3,600	1,200	20,400
10s	30	Good	.18	.01	.02	.21	21,600	1,200	2,400	25,400
3	24	Slim, lowest leaves affected	.05	.05	.01	.11	6,000	6,000	1,200	13,200
5s	24	Healthy, except few bottom leaves	.11	.03	.01	.15	13,200	3,600	1,200	18,000
4	20	Short limbs, leaves have die-back	.06	.06	.01	.13	7,200	7,200	1,200	15,600
6s	18	Healthy, except lower leaves	.16	.05	.02	.23	19,200	6,000	2,400	27,600
12	18	Healthy, except three lower leaves	.10	.06	.01	.17	12,000	7,200	1,200	20,400
34	12	Dying, some leaves dead	.19	.03	.02	.24	22,800	3,600	3,200	28,800
33	12	Leaves slightly yellow	.07	.07	.01	.15	8,400	8,400	1,200	18,000
6	12	Leaves tipped dark	.12	.02	.02	.16	14,400	2,400	2,400	19,200
15	14	Tree healthy	.10	.03	.01	.14	12,000	3,600	1,200	16,800
7	----	Dead	.08	.07	.01	.16	9,600	8,400	1,200	19,200
10	----	Dead	.05	.07	.01	.13	6,000	8,400	1,200	15,600

The *rostrata* reached its greatest height of 48 inches in presence of .05 per cent of carbonate of soda, and 36 inches in presence of .07 per cent—thus nearly equalling the *rudis.* There is not much to be said regarding other results, as the failure to do well on the part of any one of the young seedlings can not be attributed to any particular salt so far as we can determine unless it be carbonate of soda. The highest amount of total alkali in 3 feet depth in the two rows of seedlings was but .28 per cent or about 29,000 pounds per acre, and this was in a small spot in the extreme east end of the row where a few had been planted; the alkali here formed a loose covering on the ground and one of the trees, No. 34, was dying, seemingly from its effects combined with the .03 per cent of carbonate. In another place where there was a less amount of total alkali, but more of carbonate of soda, the tree (No. 6 s) was but 18 inches high and the lower leaves were dying. Other trees, where the amount of total salts was rather small but the carbonate of soda high, were dead, thus indicating that the carbonate of soda was responsible for the injury.

Where the total salts are less than .24 per cent we find that the seedling was not affected by as much as .05 per cent of the carbonate of soda; but that when the carbonate is increased to .07 per cent (8,400 pounds per acre in 3 feet depth) the leaves turned yellow. The common salt may have had something to do with the injurious effect, but the amount necessary for this does not appear in the table.

Observations in 1910.—Observations made on the Eucalyptus plot in the Tulare Station after the latter had been abandoned showed that all

of the first twelve trees of the north row had been killed, either by lack of water or by the dense mass of alkali weeds that had sprung up over the central part of the plot; the five trees of the south row included in this weed patch were also killed. All the living trees, on the outside of the patch and chiefly on the east where the weeds apparently could not grow, had made increased growth of several feet. Tree No. 15 had grown to 24 inches and No. 13 to 8 feet. In the soil of both of these trees there was but .03 per cent of carbonate of soda. On the west end of the south row, two of the trees outside of the weed patch were each 10 feet high, which was an increased growth of 6 feet in a soil containing

Fig. 6.—Eucalyptus rostrata in alkali soil; Miramonte, Kern County.

.05 per cent of carbonate of soda and which had received no irrigation during the summer.

Other Localities.—Trees of *E. rostrata* in other parts of the State were found apparently growing well in strong alkali salts and samples of their soils were taken for examination. Near Miramonte, Kern County, a group of trees six years old had a height of about 30 feet; when young they had been irrigated, but of late years have been entirely neglected and were surrounded with salt grass and alkali weeds. In this soil there was but little carbonate of soda, while the amounts of sulfate of soda and common salt were extremely large, the total being .80 per cent or 128,000 pounds per acre in 4 feet depth. Tree No. 2 was obtained near Fresno, four years old and showing no effect of the alkali salts. Nos. 3 and 4 are from Centralia schoolhouse near

Buena Park, Orange County, each a year old; one showing no effect and the other but little effect of the salts and each having about the same height. No. 5 from Buena Park, two years old and 7 feet high, in a soil having an enormous amount of alkali, but composed chiefly of sulfate of soda and common salt, showed but little injury. No. 6, from Visalia, three years old, 6 feet high, was surrounded by a crust of alkali two to three inches deep, the effect being seen in the straggling branches of the tree. Nos. 7 and 8, from Centralia, each a year old and two feet high, showed somewhat the effect of the alkali, the latter tree having some dead leaves. No. 9, from near Bakersfield, one year old, was suffering, but it was thought would live. No. 10 grew in the middle of a strip of alkali and was small and stunted. Nos. 11 and 12 were barely alive.

E. ROSTRATA IN ALKALI SOILS.

Tree No.	Locality.	Age, years.	Height.	Effect.	Percentage in soil.				Pounds per acre, 4 feet.			
					Sulfates.	Carbonates.	Chlorids.	Total.	Sulfates.	Carbonates.	Chlorids.	Total.
1	Miramonte	6	30 ft.	None	.70	.01	.09	.80	112,000	1,600	14,400	128,000
2	Fresno	4	-------	None	.09	.04	.01	.14	14,400	6,400	1,600	23,400
3	Centralia	1	2½ ft.	None	.10	.03	.02	.15	16,000	4,800	3,200	24,000
4	Centralia	1	3 ft.	Some	.11	.05	.02	.18	17,600	8,000	3,200	28,800
5	Buena Park	2	7 ft.	Some	1.48	.01	.22	1.71	236,800	1,600	35,200	273,600
6	Visalia	3	6 ft.	Some	.02	.08	.01	.11	3,200	12,800	1,600	17,600
7	Centralia	1	2 ft.	Some	.13	.05	.03	.21	20,800	8,000	4,800	33,600
8	Centralia	1	2 ft.	Some	.14	.03	.02	.19	22,400	4,800	3,200	30,400
9	Rio Bravo	1	-------	Some	.15	.01	.17	.33	24,000	1,600	27,200	52,800
10	Centralia	1	18 in.	Stunted	.17	.04	.02	.23	27,200	6,400	3,200	41,800
11	Rio Bravo	1	-------	Barely alive	.89	.02	.12	1.03	142,400	3,200	19,200	164,800
12	Rio Bravo	1	-------	Barely alive	.34	.06	.12	.52	54,400	9,600	19,200	83,200

These results appear very contradictory in regard to the amount of the several salts tolerated by the *rostrata,* and we are obliged to conclude that other causes have combined with the alkali to injure some of the trees. Some of the results are remarkable and show that under proper conditions or treatment the tree may be enabled to withstand the effect of very high percentages of each of the several salts comprising the alkali. Thus, we find that a two-year-old tree at Buena Park has reached the height of 7 feet and has suffered but little in the presence of one and one half per cent of sulfates and two tenths per cent of common salt in 4 feet depth; but there was but little carbonate of soda. These percentages represent 236,800 pounds of sulfates and 35,200 pounds of common salt per acre in that depth. Then, too, a three-year-old tree at Visalia, 6 feet high, suffered but little except in height in a soil having .08 per cent of carbonate of soda or an average of 12,800 pounds per acre in 4 feet depth. Doubtless these large amounts of alkali were largely below the reach of the tender tree roots during the

first year of growth and did not rise until the bark of the roots was strong enough to resist, thus giving time to grow downward and laterally away from the alkali.

The results thus give strong evidence of the importance of thorough and deep irrigation of Eucalyptus and other orchards in alkali lands to keep the alkali down out of reach of the roots until the latter themselves can develop and extend beyond the alkali zone.

EFFECT OF ALKALI ON EUCALYPTUS BOTRYOIDES.

No tests were made with the *botryoides* at the Tulare Station. A tree identified as *E. botryoides* was found near Kingsburg in a soil apparently strongly alkaline in character; it looked fairly well, better than a *rostrata* standing near, but seemed to show some slight injurious effect of the alkali. Black walnut trees in an adjoining lot looked very badly, half of their leaves being dead. The ground around the eucalypts had been well cultivated.

Another *botryoides,* about twelve years old, was found growing in an alkali soil near Fresno; the top was dead and the tree in a very bad condition from the alkali salts.

Samples of the soils of these two trees were taken to depths of four feet and their alkali contents ascertained as shown in the following table:

E. BOTRYOIDES IN ALKALI SOILS.

Locality.	Condition.	Percentage in soil.				Pounds per acre, 4 feet.			
		Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total
Kingsburg	Slightly affected	.04	.05	.01	.10	6,400	8,000	1,600	16,000
Fresno	Tops dead	.06	.04	.03	.13	9,600	6,400	4,800	20,800

While the tree from Kingsburg suffered but little in .05 per cent of carbonate of soda, that from Fresno, with much less carbonate in the soil but with much more common salt, was severely affected. The former tree had received good treatment, and it is to be presumed that the latter had not.

The age and height reached by these trees would indicate that with proper irrigation methods the *botryoides* can be made to withstand as much as .05 per cent of carbonate of soda in its soil without injury.

EFFECT OF ALKALI ON EUCALYPTUS ROBUSTA.

Seedlings of the Eucalyptus *robusta* were not planted in the special alkali plot of the Tulare Experiment Station, but there are two trees, one large, the other small, growing near the station fence in the Eucalyptus row which are many years old. There is some alkali in their soils as shown in the analyses given in the table.

In his search through the San Joaquin Valley, Mr. Johnson found five trees that have been identified by Professor Hall as *robusta*, growing in alkali soils. One at Kingsburg, about five years old, was but slightly affected, though it had received no cultivation and was surrounded with weeds and salt grass; a gravelly hardpan occurred at two feet below the surface, but the roots of the tree had made their way through it into the soil below.

The other trees were found near Fresno; No. 4 was two years old, about 15 feet high and showed no effect of the alkali; No. 5 was about 12 feet high, had received no cultivation, and was somewhat stunted in growth, though otherwise apparently in healthy condition; No. 6, six years old, was sickly in appearance and the edges of its leaves were dead though the tree was in full bloom. No. 7, eight years old, also appeared sickly. Its soil contained .07 per cent of carbonate of soda, or an equivalent of about 11,200 pounds per acre in 4 feet depth; the owner of the land remarked that nothing would grow upon it before the eucalypts were planted.

The alkali content of the soils of these trees is given in the following table:

E. ROBUSTA ON ALKALI SOIL.

Tree No.	Locality.	Age, years	Height, feet	Effect of alkali.	Percentage in soil.				Pounds per acre, 4 feet.			
					Sulfates	Carbonates	Chlorids	Total	Sulfates	Carbonates	Chlorids	Total alkali
1	Tulare	----	----	Small tree	.07	.03	.06	.16	11,200	4,800	9,600	25,600
2	Tulare	----	----	Large tree	.14	.02	.03	.19	22,400	3,200	4,800	30,400
3	Kingsburg	5	----	Slight effect	.12	.04	.08	.24	19,200	6,400	12,800	38,400
4	Fresno	2	15	Not affected	.05	.06	.02	.13	8,000	9,600	3,200	20,800
5	Fresno	2	12	Somewhat stunted	.06	.03	.04	.13	9,600	4,800	6,400	20,800
6	Fresno	6	----	Sickly	.09	.04	.04	.17	14,400	6,400	6,400	27,200
7	Fresno	8	----	Sickly	.08	.07	.04	.19	12,800	11,200	6,400	30,400

The treatment given the trees of the above table while young is not known, but it is evident, as remarked above, that if proper care is taken, and irrigation water applied in sufficient amount to keep the alkali down several feet and enable the young, tender rootlets to pass beyond the danger zone, before the alkali returns to the surface, a good healthy

growth may be secured in presence of even as much as .06 per cent of carbonate of soda, which is equivalent to nearly 10,000 pounds per acre. This is shown by tree No. 4 from Fresno.

Common salt has but little if any effect, for tree No. 3 from Kingsburg has withstood as much as .08 per cent (nearly 13,000 pounds per acre), even without cultivation and with other unfavorable conditions.

On the other hand, No. 7 seems to have been affected by .07 per cent of carbonate of soda (nearly 12,000 pounds per acre in 4 feet). From this we would judge that a percentage of .06 of carbonate of soda is about the upper limit of tolerance on the part of the *robusta.*

EFFECT OF ALKALI ON OTHER SPECIES OF EUCALYPTUS.

Species of Eucalyptus, other than those with which experiments have been made in the alkali plot, are growing along the south fence of the Tulare Station, having been planted in 1888 and have reached heights of from 50 to 100 feet. The list of trees in the row, beginning at the corner of the station comprise the following (as identified by Prof. H. M. Hall from specimens of flowers, etc.); the amounts of alkali salts occurring in their respective soils to a depth of four feet is given in the table:

ALKALI SALTS UNDER ROW OF EUCALYPTUS ALONG THE FENCE: TULARE STATION.

Tree No.	Species.	Percentage in soil.				Sulfates	Carbonates	Chlorids	Total
		Sulfates	Carbonates	Chlorids	Total				
1	Robusta	.142	.015	.028	.185	22,720	2,400	4,480	29,600
2	Crebra	.074	.017	.019	.109	11,840	2,720	3,040	17,600
3	Sideroxylon	.121	.010	.046	.178	19,360	1,600	7,360	28,320
4	Gunnii	.133	.007	.046	.186	21,280	1,120	7,360	29,760
5	Gunnii	.084	.019	.046	.149	13,440	3,040	7,360	23,840
6	Sideroxylon	.070	.014	.037	.121	11,200	2,240	5,920	19,360
7	Corynocalyx	.057	.029	.028	.114	9,120	4,640	4,480	18,240
8	Robusta	.074	.024	.060	.158	11,840	3,740	9,600	25,180
9	Gunnii	.117	.015	.037	.170	18,720	2,400	5,920	27,040
10	Corynocalyx	.022	.009	.019	.049	3,520	1,440	3,040	8,000
13	Rostrata	.060	.012	.009	.081	9,600	1,920	1,440	12,960
14	Sideroxylon	.044	.015	.037	.093	7,040	2,400	5,920	15,360
15	Rostrata	.056	.019	.037	.112	8,960	3,040	5,920	17,920
----	Amygdalina	.217	.017	.019	.253	34,720	2,720	3,040	40,480

In the row of trees the *amygdalina, Gunnii* No. 4 and the *rostrata* No. 1 were growing in stronger total alkali than any others, while the *corynocalyx* No. 7 is in the strongest carbonate of soda, .029 per cent. The soil of the *robusta* No. 8 has the highest amount of common salt, .06 per cent, the equivalent of nearly 10,000 pounds per acre in 4 feet.

Young seedlings of all of the above species of Eucalyptus, excepting the *amygdalina, botryoides, sideroxylon, Gunnii,* and *robusta,* have been

experimented with in the Tulare Station plot and the results are given on previous pages of this bulletin; the *robusta* and *botryoides,* on which observations were made in other parts of the State, are also discussed above with other species.

E. sideroxylon. There are three trees of this species growing in the Eucalyptus row at Tulare as shown above in the table, but in their soils there is but a small amount of alkali salts, the largest being .178 per cent. The highest percentage of carbonate of soda is in the soil of No. 14 where we find .015 per cent or the equivalent of 2,400 pounds per acre, which is quite small in a four-foot column. The largest amount of common salt is with the soil of the same tree which contains .046 per cent, or nearly 7,500 pounds per acre 4 feet depth.

The *sideroxylon* can, without doubt, withstand the effects of much larger amounts of alkali salts than found under these trees.

E. Gunnii. Seedlings of *E. Gunnii* were not planted in the test plot of the Tulare Station, and the only trees of this species growing in alkali lands that we know of are the three in the row along the station fence at Tulare, as given in the above table. The alkali in the soil of No. 4 is greater than in that of any of the trees of the row (.186 per cent) but is not excessive. The highest carbonate of soda under the *Gunnii* is .019 and of common salt .046 per cent, and these have not produced any apparent injury. Both the *sideroxylon* and the *Gunnii* can, almost without doubt, withstand as much carbonate of soda as other species of eucalypts which has thus far been placed at .04 per cent in a depth of three feet.

E. amygdalina.—The *amygdalina* is standing in a soil containing the highest total alkali of the group, .253 per cent, or about 40,000 pounds per acre in 4 feet depth, but the amounts of carbonate and common salt are only .017 and .019 per cent (2,700 and 3,000 pounds) respectively. The species can without doubt do well in as much as .04 per cent of carbonate of soda.

SUMMARY OF RESULTS.

The highest percentage of carbonate of soda found in the soils of the respective species of eucalypts, and the condition of the tree in presence of these percentages, both in the seedling test-plot at Tulare and at outside places are given in the following summary:

Species.	Tulare seedlings: soils 3 feet deep.			Trees growing elsewhere; soils 4 feet deep.		
	Carb. soda. per cent.	Condition.	Height.	Carb. soda. per cent.	Condition.	Height.
Crebra	.10	Dying	6 inches	.02	Healthy	Tall
	.08	Dying	10 inches			
	.07	Poor growth	6 inches			
Rudis	.08	Good	36 inches	.09	Not growing	
	.07	Good	24 inches	.08	Leaves spotted	6 feet
Tereticornis	.07	Leaves dying	18 inches			
	.08	Dead	4 inches			
Corynocalyx	.08	Leaves dying	18 inches	.07	Leaves yellow	25 feet
	.05	Dead	6 inches			
Globulus	.07	Dwarfed	18 inches	.14	Stunted, not thrifty	
	.06	Dead	8 inches	.07	Sickly; 8 years old	
Rostrata	.07	Good	36 inches	.08	Not full grown; 3 years old	
	.05	Good	48 inches	.05	Little effect	
Cornuta	.07	Leaves dying	20 inches			
	.05	Dead	24 inches			
Robusta				.07	Sickly	
				.06	Not affected	6 feet
Botryoides				.05	Slightly affected	
Sideroxylon				.02	Large tree not affected	
Gunnii				.02	Large tree not affected	
Amygdalina				.02	Large tree not affected	

Among the young trees at Tulare in the above table the *crebra* was exposed to the highest amount of carbonate of soda, but only grew a few inches and finally died. The *rudis* alone made good growth in as much as .08 per cent, though with .09 per cent in an outside grove it was alive but not growing. The *rostrata* in an outside grove three years old had its growth retarded by .08 per cent, but at Tulare the seedling made good growth of 36 inches in presence of .07 per cent. The *globulus* was stunted by .14 per cent, made less than half growth with .07 and was dead with .06 per cent of carbonate of soda.

The highest amount of carbonate of soda found in any soil during this investigation was .20 per cent (32,000 pounds per acre) in a depth of 4 feet in a Eucalyptus plantation near Pixley. A two-year-old tree growing in it, not identified but supposed by Mr. Johnson to be a *corynocalyx,* had made a growth of but 3 feet. It was in a sandy soil, and

had had good cultivation and irrigation, which had evidently kept the corrosive carbonate of soda below the tender surface roots, thus affording a good illustration of what proper treatment will do in helping a seedling to escape severe injury in a soil containing large amounts of alkali salts. The next highest amount of carbonate of soda given in the tables above was that of .14 per cent in which a *globulus* was slowly growing.

The following table presents the highest percentages of carbonate of soda found in the soil of such seedlings of each species of Eucalyptus that at the end of the first season at Tulare had reached their highest growth and remained healthy:

Species.	Height.	Carbonate of soda.	Pounds per acre of carbonate of soda.
E. rudis	36 inches	.08 per cent	9,600
	24 inches	.05 per cent	6,000
E. crebra	6 inches	.07 per cent	8,400 little growth.
E. rostrata	48 inches	.05 per cent	6,000
	36 inches	.07 per cent	8,400
E. globulus	30 inches	.04 per cent	4,800
	18 inches	.04 per cent	4,800
E. corynocalyx	30 inches	.04 per cent	4,800
	24 inches	.04 per cent	4,800
E. tereticornis	24 inches	.04 per cent	4,800
E. cornuta	42 inches	.03 per cent	3,600
	24 inches	.04 per cent	4,800

From the above table it will be seen that the *E. rudis* among the seedlings at Tulare, reached its highest growth, unaffected, in a higher percentage of carbonate of soda than did any other species; the soil of this seedling contained .08 per cent of the carbonate or an average of nearly 10,000 pounds per acre in a depth of 3 feet. This, with the fact that not one of its seedlings was killed in the test row while all other species lost numbers of their seedlings, would seem to place the *rudis* as first among alkali-resistant eucalypts.

The *rostrata,* with its tall growth of 48 inches in .05 per cent of the carbonate, and 30 inches in .07 per cent, marks it as next to the *rudis* in its resistance to alkali effects.

While the *crebra* seem to rank next to the *rudis* with its .07 per cent of carbonate, its very slow growth of but about four inches in the season, and the general injurious effect on all of its trees, in reality places it below even the *cornuta* at the bottom of the list.

The other species, except the *cornuta* and *crebra,* so far as the present records go, are about equal in their tolerance of carbonate of soda, and we may safely place the amount at .04 per cent or about 5,000 pounds

per acre distributed in the upper 3 feet of soil; or possibly 6,500 pounds if distributed through 4 feet depth.

The eucalypts thus seem to have a higher toleration for carbonate of soda than do many orchard trees, and are apparently not sensitive to very large amounts of the sulfates and of common salt if distributed through the upper soil instead of being accumulated on the surface.

CONCLUSIONS.

A general review of the work thus far done with regard to the effect of alkali salts upon several species of Eucalyptus brings out the following conclusions based upon the results obtained:

1. The limit of tolerance of alkali salts upon the part of the Eucalyptus is greater in soils well taken care of than in poorly treated ones. Care in the cultivation and irrigation of the young trees is highly important in plantations of eucalypts, as well as in other cultures.

2. A higher percentage of alkali salts, and especially of carbonate of soda, may be tolerated by young Eucalyptus if the alkali be kept below the roots or at a depth of several feet, until the roots have passed beyond the alkali bed both downward and laterally, and the bark of the roots has become sufficiently thick to resist corrosion.

3. The carbonate of soda is proven by the observations to be the chief hurtful ingredient in alkali. The sulfates and chlorids, even in large amounts have but little injurious influence on the young eucalypts, so long as they do not form a thick crust on the surface of the ground; the *globulus* grew to a height of 60 feet on the levee of one of the islands in the tule marsh lands of the Sacramento and San Joaquin rivers, the soil of which contained about 40,000 pounds of common salt in a depth of two or three feet. The carbonate of soda may be neutralized and changed to non-injurious sulfates by the application of sufficient amounts of finely ground gypsum with an abundance of irrigation water.

4. The value of Eucalyptus trees being dependent on their size, the seedling should not be planted in alkali soil having such a percentage of carbonate of soda that would dwarf or even retard the growth, unless precautions be taken to keep the alkali below the young root system for a couple of years or more. A percentage of from .07 for many of the species and .09 for the *rudis* and *rostrata* seems to have this retarding effect on the growth, but the generous application of gypsum should counteract this.

5. Of the species of eucalypts tested at the Tulare Station, the *rudis* reached its best growth, in a higher percentage of carbonate of soda than did any of the others. Its .08 per cent is equivalent to nearly 10,000 pounds per acre in a depth of 3 feet.

The *rostrata* stands next to *rudis* in its resistance to alkali at the

Tulare Station (.07 per cent) while the *globulus, corynocalyx, tereticornis,* and *cornuta,* each reached their maximum growth in but .04 per cent of carbonate of soda, being apparently retarded by a larger amount.

The *crebra,* while apparently healthy with as much as .07 per cent of carbonate of soda, had made scarcely any growth in the first season, and can hardly be called an alkali-resistant species.

6. The beneficial effects of good care and irrigation are shown by a tree supposed to be *corynocalyx* growing near Fresno in a soil containing as high as .20 per cent of carbonate of soda in a depth of 4 feet. In this instance, the alkali had evidently been largely kept away from the young rootlets by the abundant irrigation and cultivation of several years until the danger point had been passed.

7. In general, a percentage of .04 of carbonate of soda in 3 feet depth (or about 5,000 pounds per acre) was easily tolerated without injury by each of the species of eucalypts tested at Tulare, and doubtless will be by many others.

Further observations will probably place the limit of tolerance at a higher figure than at present determined for the several species.

CULTURE METHODS AND USES OF EUCALYPTUS.

(Partial Reprint from Bulletin 196.)

[The edition of Bulletin 196 of this station, entitled "Eucalyptus in California," by Mr. Norman Ingham, in charge of the Santa Monica Station, has been entirely exhausted, and the request for copies is so great that it has been thought best to reprint such portions of it as relate to cultural methods and uses, and the descriptions of those species on which alkali observations have been made. These are abstracted in abbreviated form, substantially as given by Mr. Ingham in his bulletin. Extracts have also been made from the admirable publications of Mr. Abbot Kinney of Los Angeles and Baron von Mueller of Australia, in which they describe the numerous species of Eucalyptus. Mr. Ingham, however, cautions eucalyptus planters not to rely on Australian experience as plantings in California seem to show material differences in success.]

Eucalyptus planting has now passed the experimental stage and may be considered without question as a commercial proposition. The value of the crop and the possibilities of growing it in California have been sufficiently demonstrated to make judicious plantings even on a large scale perfectly safe, with an assurance of sure and reasonably large profits. It is important, however, for the planter to consider, in the light of the best information, the nature of the product which he will produce, or, in other words, the market which he will attempt to supply with the Eucalyptus trees.

Since the introduction of the first species of Eucalyptus, the seeds of other species have been imported each year by seedsmen, nurserymen, and in many cases ranch owners until at the present time there are growing in the State nearly one hundred species. The University of California has seventy named species growing on the forestry station grounds at Santa Monica, California; there are specimen trees of nearly every species over ten years of age and bearing seed at the present time, while there are young trees of all the promising lumber eucalypts.

From this large collection there can be selected species that will grow on nearly any soil in a frostless region, while there are a few that can endure a temperature from 20° F. to 120° F, and at different altitudes; but with these trees it is as with any other, there is one location best adapted to the greatest development; it may be a situation near the coast in a foggy atmosphere, the river bottoms, the inland valleys or in swamps. Care should be taken in selecting a species for any certain locality, that the conditions there are the ones that will bring the species in question to the highest point of development.

EUCALYPTUS FOR TIMBER.

The wood of the different species of Eucalyptus varies from a wood as soft as that of our pines, to very hard, closed-grained and variously colored kinds equal to our native oaks and hickories. Among the large number of species may be found some that can be substituted for nearly all our present commercial woods, although the Eucalyptus wood is harder to work.

Eucalyptus timber is more costly to cut and mill than any of our native hardwoods; in planing, the lumber of many of the species has a tendency to chip on account of the irregular grain, while that of all of the species under the most careful handling season-cracks more or less on the ends. This fault can be overcome by having the logs sawed a foot or two longer than the finished product needs to be so that the season-cracked ends can be removed. Very little trouble is experienced in seasoning the lumber if the trees are cut down during the winter months and sawed while green, and the lumber then piled in high tiers to obtain weight, in some places protected from the wind and sun.

Strength Tests of Eucalyptus.—We reproduce the following, bearing on the strength of several species of Eucalyptus timber:

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.

Trade Bulletin 8. October 8, 1906.

EUCALYPTUS FOR TIMBER.

The wood of the eucalypts has not been extensively used by manufacturers in the United States, because the supply has not been sufficient to establish a market. Blue gum, the most common species in California, has, however, competed with black locust for insulator pins, has given satisfactory service in chisel and hammer handles, and has been used locally for wagon tongues, axles, spokes, hubs, and felloes. It is hard, strong, and tough.

In coöperation with the State of California, the Forest Service recently completed a study of the mechanical and physical properties of the common eucalypts. The tests, made at the State University at Berkeley, were to determine whether Eucalyptus can be substituted for some of the hard woods that are becoming difficult to obtain.

Blue gum is by far the fastest growing species. The height and diameter of trees from which the test pieces were taken is given in the following table. All the trees were about fifteen years old:

Species.		Diameter, inches.	Height, feet.
Common name.	Botanical name.		
Blue gum	Eucalyptus globulus	30	101
Sugar gum	Eucalyptus corynocalyx	15	73
Karri	Eucalyptus diversicolor	16	72
Manna gum	Eucalyptus viminalis	12	60
Red gum	Eucalyptus rostrata	9	47
Leather-jacket	Eucalyptus punctata	10	43
Red mahogany	Eucalyptus resinifera	8	38

An important point in considering the value of commercial plantations of eucalypts is brought out in the next table, which shows that the fastest growing species are also the strongest. The tests were made upon kiln-dried material.

Species.	Bending.			Compression parallel to grain.	
	Age in years.	Number of tests.	Modulus of rupture pounds per square inch.	Number of tests.	Crushing strength, pounds per square inch.
Sugar gum	15	5	25,344	11	11,290
Blue gum	30	12	23,265	15	12,310
Leather-jacket	15	3	19,267	10	10,908
Karri	15	8	18,386	17	8,795
Blue gum	15	28	16,900	34	8,190
Red mahogany	15	4	14,550	2	7,920
Red gum	15	9	14,380	6	7,723
Manna gum	15	12	13,093	20	7,309

A comparison with Forest Service tests on hickory shows that 30-year-old blue gum is stronger than XXX hickory, and that 15-year-old sugar gum is nearly as strong as black hickory and 91 per cent as strong as second-growth hickory.

The wood of very young and sappy trees is apt to warp, but that from more mature growth can be easily handled to prevent warping. Early seasoning should proceed slowly. Open piling is desirable; the stacks should be high to secure weight, and should be covered.

Several of the Eucalyptus grow rapidly in California, and, under forest conditions, form straight, tall poles free from branches. They have, therefore, especial value as timber trees.

EUCALYPTUS FOR FUEL.

The wood of most of the eucalypts makes good fuel. A grove of blue gums five years old, set out 6 by 6 feet apart, under favorable conditions should yield from 50 to 80 cords of wood per acre, while at ten years of age 80 to 150 cords may be expected. Groves under irrigation will undoubtedly do better than the above figures indicate, while the quality of the land will also, of course, have a great influence. The cost of working up the standing trees into fuel ready to burn varies somewhat with the age and species of the trees.

EUCALYPTUS FOR OIL.

The leaves and twigs of the tree, when distilled, produce an oil which has great medicinal properties and is used quite extensively in medicine at the present time. This oil is a non-irritant antiseptic, which can be used without the slightest injury on all the tissues of the body and internally in very small quantities. The amount of oil that can be extracted from a certain number of pounds of leaves and twigs varies with the locality in which the grove is situated, in the different trees according to their positions in the grove and in the different species of Eucalyptus. The latter is also true in regard to its medicinal properties.

The leaves from the brush of ten cords of wood, cut from the *globulus* five years of age distil from one and a half to two and a half gallons of oil, or two tons of leaves and twigs will produce from three to four gallons.

According to Von Mueller, the following percentages of oil are obtained from the foliage of a number of species:

Species.	Volatile oil.
E. amygdalina	3.313 per cent
E. oleosa	1.250 per cent
E. leucoxylon	1.060 per cent
E. goniocalyx	0.914 per cent
E. globulus	0.719 per cent
E. obliqua	0.500 per cent

The lesser quantity of oil of *E. globulus* is, however, compensated for by the vigor of its growth and the early copiousness of its foliage. *E. rostrata,* though one of the poorest in oil, is nevertheless important for malarial regions, as it will grow well on periodically inundated places and even in stagnant waters not saline. Eucalyptus oils dissolve the following, among other substances for select varnishes and other preparations; camphor, pine resins, mastic, elemi, sandarac, kauri, dammar, asphalt, benzoe, copal, amber, shellac, caoutchouc, also wax but not gutta-percha. These substances are arranged in the order of greatest solubility.

THE EUCALYPTS AS BEE PASTURE.

All of the eucalypts have more or less value as bee pasture when in bloom, and from the large number of species growing in the State it is possible to select a group that will furnish bloom for the bees to work on the year round. If the natural pastures are good for all but a short period each year, it is possible to select one or two species of Eucalyptus that will fill in that time.

The list given below is made up from the data collected from two years' observation of the blooming periods of the Eucalyptus species on the Forestry Station ground. The names of the species are put down for the months when the most of the trees of that species are in bloom, although there are instances in every species where some one individual specimen will be found blooming at an entirely different period, or perhaps twice during the year. Some of the species have been considered injurious to bees, but we have never been able to find dead bees under the tree. The bees seem to have a preference for the white or greenish white flowers:

January: *globulus, leucoxylon, siderophloia, robusta,* and *melliodora.*

February: *globulus, robusta, polyanthema, leucoxylon,* and *melliodora.*

March: *globulus, robusta, leucoxylon, polyanthema, melliodora,* and *sideroxylon* var. *rosea.*

April: *leucoxylon, melliodora, Gunnii, polyanthema,* and *Stuartiana.*

May: *melliodora, Gunnii, maculata, cornuta, rostrata,* and *tereticornis.*

June: *melliodora, maculata, cornuta, tereticornis, rostrata,* and *citriodora.*

July: *citriodora, tereticornis, rostrata, viminalis, cornuta,* and *eugenioides.*

August: *viminalis, cornuta, Lehmannii, eugenioides, calophylla, corynocalyx,* and *resinifera.*

September: *Lehmannii, corynocalyx, calophylla,* and *resinifera.*

October: *calophylla, corynocalyx,* and *siderophloia.*

November: *corynocalyx, siderophloia, leucoxylon,* and *robusta.*

December: *globulus, robusta, leucoxylon,* and *sideroxylon* var. *rosea.*

EUCALYPTUS ADAPTED TO SPECIAL PURPOSES.

The species whose wood is the most durable in the soil:

Eucalyptus rostrata, tereticornis, rudis, diversicolor, sideroxylon var. *rosea, corynocalyx, citriodora,* and *crebra.*

The lumber species:

All of the species described herein are valuable as lumber trees, although the four following are considered the best among the eucalypts as commercial lumber trees: *Eucalyptus globulus, rostrata, tereticornis,* and *corynocalyx.*

The species for fuel alone:

All of the species are of more or less value for wood, but the following two species will produce more wood than any of the others on any good land. These two are the common blue gum, *Eucalyptus globulus,* and *viminalis,* the two most rapid growing gums we have in this country.

The most frost-resistant species:

Eucalyptus rostrata, globulus, viminalis, tereticornis, sideroxylon, crebra, rudis, robusta, resinifera, and *Stuartiana.*

Drought-resistant species:

Eucalyptus corynocalyx, microtheca, polyanthema, and *cornuta.*

POTASH IN EUCALYPTUS.

The potash obtainable from the ashes of various eucalypts varies from 5 to 27 per cent. One ton of fresh foliage of *E. globulus* yields about 8½ pounds of pearl-ash; a ton of the green wood, about 2½ pounds; of dry wood about 4½ pounds.

PLANTING AND CULTIVATION OF EUCALYPTUS.

Quality of Soil for Eucalyptus Planting.—The idea is too prevalent that Eucalyptus growing is exclusively a proposition for cheap, dry, or poor land. It is true that the trees, especially certain species, will live and grow fairly well under conditions where no other crop could be considered, and if the object is merely the utilization of such land to the best advantage Eucalyptus planting may be wise and somewhat profitable. For one, however, who is buying land for this purpose, or one who already has fairly good land capable of irrigation or naturally moist, it is becoming more and more apparent that good land, capable of culture and irrigation, will produce far more profitable returns on the investment by reason of the enormously more rapid growth and greater wood production of the trees. Under such conditions a crop of trees may be produced and marketed and the land then cleared for other purposes, or the stumps allowed to sprout for a second crop, when on poor, dry land, trees of the same age would not pay for cutting.

METHODS OF GROWING EUCALYPTUS.

The necessary conveniences for the propagation of the seedlings are as follows: seed boxes or flats, a good soil, seed true to name, plenty of water convenient to all flats, and in most localities a shade for the young plants from the sun is required.

The Soil for the Seed-bed.—It has been proven that Eucalyptus seeds will germinate and grow in nearly any soil, from a clear beach sand to adobe, but the best results are obtained if the seeds are sown in a light loam; in the transplanting flats a medium loam, mixed with about one fourth of well rotted manure, should be used.

Shade for the Young Plants.—Where a large number of plants are to be grown, a lath house, with the laths spaced their own width apart for the protection of the young plants from the midday sun, will be found more convenient than lath or cheese cloth screens laid on small frames above the flats, as the labor required to move them each time the plants are watered would amount to a large item of expense during the growing season. The lath house or the screens will also protect the seed flats from the ravages of the birds and the young plants from the frosts (if not too severe) during the cold weather of the winter months, before the time for setting in the field.

Time to Sow the Seed.—The time to sow the seed varies somewhat with the locality, but, as a general rule, the seed should be sown by the latter part of June or first of July, and the seedlings from these sowings will be large enough to be set out in the field the following spring, if they receive proper care while young.

Methods of Sowing the Seed.—The seed is generally sown broadcast in the seed-flats and the young plants transplanted once before being

set in the field; while others sow the seeds in hills and practice thinning instead of transplanting before setting out in the field. With either of these methods the flat is filled to a depth of two and one half inches with the prepared soil, pressing it down firmly in the boxes, the seed is sown and covered to a depth of not over one fourth of an inch with the same soil, sand or sawdust, pressing the covering firmly. The number of fertile seeds of any species to the pound is very high; the average number of transplanted plants raised to the pound is 12,000. The seed-flats should be kept damp through the heat of the day, until the young plants break through the ground, then care must be taken not to use too

FIG. 7.—Eucalyptus seedlings, *rudis* and *viminalis*.

much water and that there is good circulation of air over the flats, or the fungous disease "damping off" is liable to occur. This disease is most general on damp, cloudy days, and where the plants are watered late in the evening. Some species most susceptible to damping off are the *E. corymbosa, citriodora, calophylla, ficiofolia,* and *globulus.*

Transplanting.—The seeds that have been sown broadcast in the flats can be transplanted, when the plants are two or three inches high, to other flats of prepared soil and spaced from one and a fourth to two inches apart; the soil should be kept damp and the plants protected from the direct rays of the sun for a few days.

The time to set the plants in the field varies with the climatic conditions or localities, and whether the plants are to receive irrigation or not. In localities where frosts are common through the winter months, it is

advisable to set the trees out as early in the spring as possible without endangering them to a late frost and still have them receive the benefits of the late rains, so that they will have a full season's growth to withstand the frosts of the following winter. If trees are to be irrigated they can be set out later in the season without danger of loss from want of moisture.

The size of the plants when set out in the field should not be under six or over ten inches in height, to secure a good stand. The land should be thoroughly plowed and harrowed before planting. The distance apart at which the seedlings should be planted depends upon the species of Eucalyptus, the soil, the distance to water and whether the trees are to be grown for fuel, ties, or lumber. Some of the species are naturally straight-growing trees, while others grow out of the perpendicular unless set in close plantings. In a rich, heavy, loam soil they may be planted as close as 6 by 6 feet or if irrigated 4 by 8 feet; on lighter soil 8 by 8 feet is the proper distance, or 6 by 10 if irrigation is practiced. The close planting has a tendency to sacrifice the diameter growth in favor of height, also making more erect trees and forming a perfect canopy with their crowns that will shade the soil, nearly preventing evaporation of the soil water.

Cultivation of the young trees should be carried on as long as possible without danger of injuring them; they can generally be cultivated for the first season and part of the second before the limbs of the trees spread out and interlap so as to make it impossible to drive between the rows.

Thinning of the Young Trees.—It is a self-evident fact that to grow large trees for lumber a greater space than 6 by 6 feet is needed for each tree to reach a large diameter, but at the same time it would be good management to set out just the number of trees to the acre which are expected to mature. Trees are killed by gophers and rabbits and by extremes of temperature, and it is practically impossible to replant in the missing spaces after the trees are one year old. A planting upon any good soil may with advantage be set out 6 by 6 feet apart and at the end of the first year a rigid thinning should be started, removing with a grub hoe all weak, inferior or injured trees. This thinning should be carried on until only the strong and healthy trees, or a certain number, remain to the acre.

The value of a plantation when ten years old will depend most largely on the care it has received during the first four or five years of its growth. One of the most essential points in regard to the growing of perfect trees is that they start to grow erect with clean trunks the first few years. Some trees will naturally start in this way, while others fork, producing a number of lateral branches on their trunks; each year

all limbs that have a tendency to deform the trees should be removed. After the third or fourth year the trees will have grown to such a height that to remove the limbs may prove impracticable in most cases, and then the poorer trees should be removed for wood or stakes to allow the remainder a larger area of soil to draw upon and a greater space above ground to extend their branches. At this time the trees on an acre can be reduced to a certain number, leaving those to grow for telephone poles, ties or lumber; or the entire grove may be cut for stakes and wood.

Sprouts.—Sprouts will start from the stumps in from three to six weeks from the date the trees are cut down, in any month of the year. The number of sprouts to the stump is generally large and varies with the species as shown in the following:

Species.	Diameter of stump.	Number of sprouts.	Height of sprouts.
E. polyanthema	3 feet	15	71 inches
E. stuartiana	5½ feet	59	71 inches
E. viminalis	11 feet	16	65 inches
E. corynocalyx	5½ feet	35	[illegible]2 inches
E. siderophloia	4½ feet	55	47 inches
E. globulus	7½ feet	21	45 inches
E. punctata	5 feet	42	45 inches
E. tereticornis	4½ feet	2	42 inches
E. leucoxylon	5½ feet	52	41 inches
E. rostrata	5¼ feet	8	41 inches

The stump of the *globulus* had been driven over and many of the sprouts destroyed. To obtain the largest profits from the sprout growth in the shortest time, it is necessary to go over the planting, when the sprouts are from six months to a year old, and remove all but two to four of the largest and most erect growing, leaving them well spaced around the stump; if all of the sprouts are allowed to remain their growth is retarded.

The number of cords per acre at the second cutting is greater for the same length of time, and is due to the fact that the three or four sprouts make a more rapid growth than the parent tree because of a fully developed root system which is capable of supplying the food to a mature tree.

DESCRIPTION OF SPECIES OF EUCALYPTS.

Mr. Ingham selects the following eighteen of the many species of Eucalyptus as being the most promising for commercial planting in California, and describes each in his bulletin:

E. botryoides	*E. viminalis*
corynocalyx	*citriodora*
crebra	*corymbosa*
globulus	*diversicolor*
robusta	*leucoxylon*
rostrata	*polyanthema*
rudis	*punctata.*
sideroxylon var. *rosea*	*resinifera*
tereticornis	*siderophloia*

Those of the first column comprise the species which have been tested more or less as to their tolerance for alkali salts, and whose descriptions by Mr. Ingham are repeated in this bulletin. To these are added *E. Gunnii* and *amygdalina* from the publications of Mr. Abbot Kinney and Baron von Mueller. The illustrations given of these species are from the bulletin of Mr. Ingham.

For fuller details, and for descriptions of other species than given here, those interested are referred to the publications of Professor McClatchie and Messrs. Abbot Kinney, von Mueller, and Ingham.

Eucalyptus Amygdalina. Brown or White Peppermint Tree.

The following description of this important species of Eucalyptus is given by Baron von Mueller. In sheltered, springy, forest glens it attains exceptionally a height of over 400 feet there forming a smooth stem and broad leaves, producing seedlings of a foliage different from the ordinary form of *amygdalina,* which occurs in more open country and has small, narrow leaves and a rough, brownish bark. The former species or variety, which has been called *E. regnans,* represents probably the loftiest tree on the globe, attaining a height of 415 feet with a diameter of 15 feet, a considerable distance above ground. Another tree measured 69 feet in circumference at the base of the stem; at 12 feet above ground it had a diameter of 14 feet, at 78 feet a diameter of 9 feet; at 144 feet a diameter of 8 feet, and at 210 feet a diameter of 5 feet. The wood is fissile, well adapted for shingles, rails, staves, inner building material and many other purposes, but it is not a strong wood. That of the smaller, rough, barked variety has proved lasting for fence posts.

It has endured the frosts of the milder parts of England with *E. Gunnii* and *cordata.* In New Zealand it has survived the cold where *E. globulus* succumbed. This species yields more volatile oil (3.3 per

cent in the foliage) than any other hitherto tested and is therefore largely chosen for distillation.

Mr. Abbot Kinney says that while *E. amygdalina* of Australia is the tallest tree in the world, yet the *amygdalina* in southern California has in no case equalled in size local blue gums. Its manner of growth here gives little prospect that it will ever surpass *E. globulus*.

Eucalyptus Botryoides. Bastard Mahogany.

From East Gippsland to South Queensland. Vernacular name Bastard Mahogany, and a variety called Bangalay, the latter generally found on coast sands. One of the most stately among an extensive number of species remarkable for its dark-green shady foliage. It delights in river banks, but it will thrive also on ground with stagnant moisture. Grows splendidly at the city of Algiers (Prof. Bourlier). Stems attain a height of 80 feet without a branch and a diameter of 8 feet. The timber usually sound to the center, adapted for waterworks, wagons, particularly for felloes, also knees of boats. Posts formed of it are very lasting, as no decay was observed in fourteen years; it is also well adapted for shingles. (Von Mueller.)

Mr. Norman Ingham, in charge of the Santa Monica Station, in Bulletin No. 196 of this Experiment Station, says of the *botryoides:* The trees of this species are very erect in growth, but branched; the bark of the trunks of the old trees is reddish-brown in color, rough and nearly persistent; the limbs are generally smooth, shedding their bark in long strips. The leaves are lance-shaped, leathery in texture; in color the upper surface is a dark green, while the lower surface is much paler. The flower clusters are borne laterally on compressed stalks. The seed cases are five to seven in number, deep, cup-shaped and stemless.

The timber of this species is considered by the Australian writers to be one of the best of eucalypts, when it is grown where there is plenty of water. It makes the best of wind-breaks and is one of the best eucalypts to use as a shade tree.

Eucalyptus Corynocalyx. Sugar Gum.

Trees of this species in close planting grow erect, having a very open crown, while individual specimens branch low, with the branches scattering. The bark of the trunks of the old trees is deciduous, and of a scaly appearance, due to the unequal flaking off at different times of the year. In color it varies from a cream to a dark gray.

The branches are smooth, shading off in color to a light green, while the twigs, young seedlings and sprouts are of a reddish hue. The leaves of the young plants are ovate, dark green in color on the upper side of the leaf and several shades lighter underneath. Those of the old trees

FIG. 8.—Eucalyptus botryoides. Natural size.

are long, slightly curved and sharply pointed, somewhat leathery in texture, dark green on the upper side and lighter in color beneath.

The buds are borne laterally and bloom during August and September; umbels alternate, solitary, pedicles short, the buds with their deciduous calyx cups are dumb-bell shaped, while the mature fruit is egg-shaped, with the valves three or four in number, generally three, enclosed. The seed ripens during the summer months and is brown in color and the size of the blue gum seed, but not so angular.

The lumber of the sugar gum is of a yellowish white color, easy to work when green but very hard if allowed to dry. This wood is very closed grained and hard, and tested very high at Berkeley in the tests carried on by the United States Forestry Service. The wood can be used for the same purpose as the blue gum wood, and is durable underground.

Trees of this species reach their best development in the southern part of the State. The sugar gum has been given a thorough trial in both the San Joaquin and Sacramento valleys, but in every case known to the writer they have been killed by the frost. Some of the best growths of this tree can be seen at Riverside, or in the towns along the coast from San Diego to Santa Monica. This is one of the trees much used in southern California as a street tree, especially at and around San Diego. It is to be found growing as wind-breaks around Riverside, San Bernardino, Colton, Ontario, Pomona, and San Dimas.

This species is one of the most drought resistant and valuable eucalypts that can be set out commercially, but it succumbs to frost. It is of a much slower growth than the other commercial eucalypts, coming after *rostrata,* as a rule.

Von Mueller says of the *corynocalyx:* A timber tree attaining a height of 120 feet, length of bole to 60 feet, circumference at 5 feet from the ground reaching 17 feet. The base of the trunk often swells out in regular tiers. The wood remarkably heavy, very dense, hard and strong, less liable to warp than that of many other kinds of Eucalyptus wood (J. E. Brown). It has come into use for fence posts and railway sleepers, naves and felloes. Its durability is attested by the fact that posts set in the ground fifteen years, show no sign of decay. The tree thrives well even on dry ironstone ranges. The sweetish and pleasantly odorous foliage attracts cattle, sheep and camels, which browse on the lower branches, as well as on saplings and seedlings. Scarcely any other eucalypt is similarly eaten (J. E. Brown). It should, therefore, be planted on cattle- and sheep-runs in arid districts, to furnish additional provender.

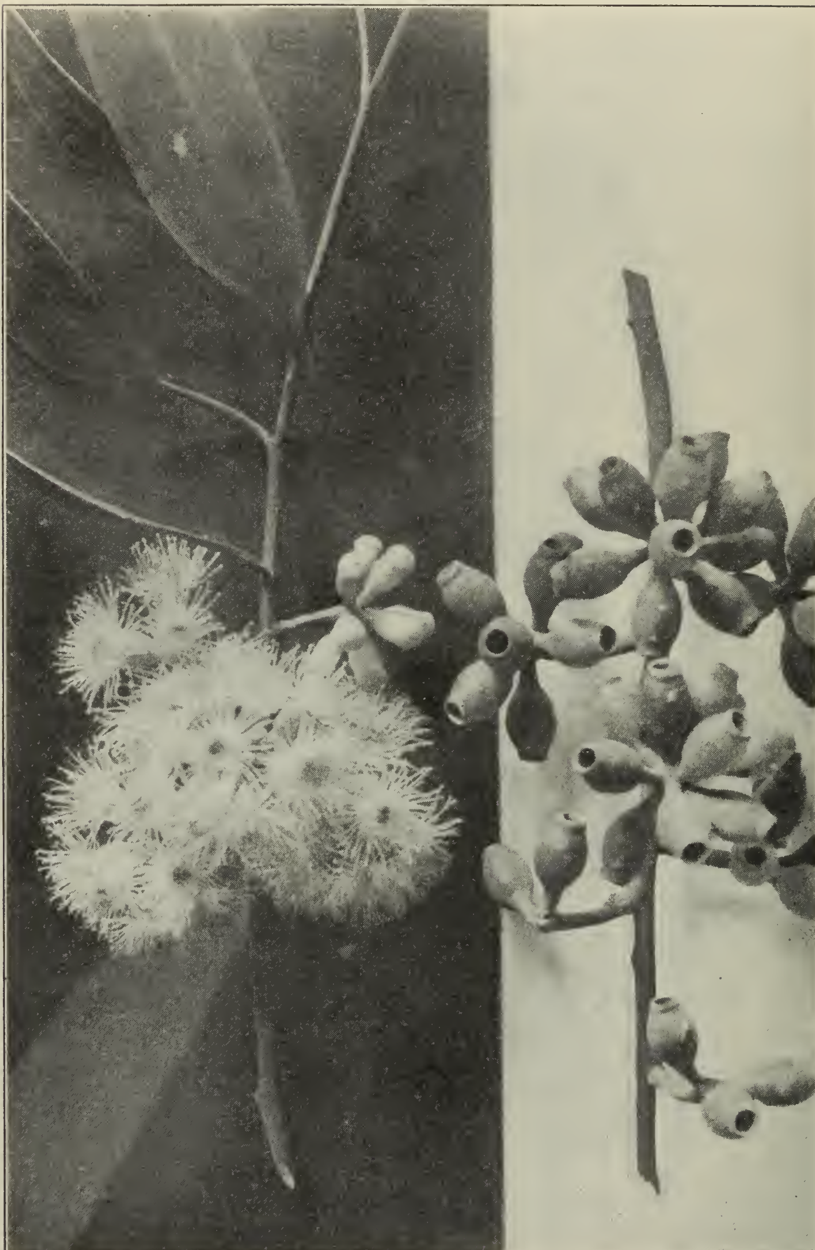

FIG. 9.—Eucalyptus corynocalyx. Natural size.

Eucalyptus Cornuta. The Yate.

Eucalyptus cornuta, the "yate," is a very attractive, graceful tree. Its foliage is greener than that of the blue gum, and tends to persist in the round or oblong form of leaf. It is a rapid grower and resists drought on light soil better than *E. globulus* or *E. viminalis. Eucalyptus cornuta* is one of our hardiest and fastest growing Eucalypti. The bark is a pleasant light drab color and nearly smooth. The tree grows tall, has great vigor in our valleys, and the timber is valuable. While it does branch low it makes a large, handsome tree with plenty of foliage. The flowers are so large and close in the umbel that each umbel looks like a large, single, pompon flower of delicate light green or light straw color. Its name comes from the long, horn-like cap of the flower. (Abbot Kinney.)

Von Mueller says: The yate tree of southwestern Australia is a large tree of rapid growth, preferring a somewhat humid soil. The wood is used for various artisans' work, and preferred there for the strongest shafts and frames of carts and other work requiring hardness, toughness and elasticity, and is considered equal to ordinary ash wood. The tree appears to be well adapted for tropical countries.

Eucalyptus Crebra.

The narrow-leaved ironbark-tree of New South Wales and Queensland. Wood reddish, hard, heavy, elastic and durable; much used in the construction of bridges and for railway sleepers, also, for wagons, piles, fence posts. This species is of an erect growth and has a very rough, persistent bark of a light grayish color, the rough bark extending to the limbs and small twigs, which are smooth. The leaves are long, narrow, equally dark green on both sides and pendulous, giving the trees a weeping effect. The mature seed cases are borne in paniculated umbels, and are small cup-shaped, with the valves, generally four in number, enclosed. The wood is hard, durable and of a reddish color, considered valuable. This species has the power to resist frosts and is found growing in Fresno and in the southern part of the State. It is being set out in great numbers at the present time by companies, in commercial plantings. In rapidity of growth this species ranks near the *Eucalyptus rostrata.*

Eucalyptus Globulus. Blue Gum.

Individuals of this species grow erect as a rule, branching low in isolated specimens, while those in close plantings have small crowns and are practically free from lateral branches. The bark of the seedlings is light bluish green in color, while that of the trunks of the old trees varies from a light brown to a gray or greenish color due to the flaking off of the bark in long strips. The limbs are generally smooth.

FIG. 10.—Eucalyptus crebra. Natural size.

The stems of the seedlings are rectangular in shape, while their leaves and those of the sprouts of the old trees are opposite, oblong, blunty pointed, and of a light bluish green color, darker on the upper side of the leaf. Those of the old trees are elongated, sickle-shaped, leathery in texture, and equally dark green on both sides.

This species is in bloom from January to May, the flowers being white in color, generally solitary, axillary and borne on short stalks. The whitish buds are angular, with a bluntly-pointed saucer-shaped deciduous cap, while the mature fruit is dark green in color, with from three to five valves, generally four, barely enclosed.

Trees of this species endure the frosts of the Sacramento Valley as far north as Red Bluff, Tehama County, and the dry heat of the San Joaquin Valley. It is found in nearly every town south of San Francisco to San Diego, and out of the edge of the Imperial desert region. A large number of blue gum seedlings have been set out in Imperial Valley, but nearly all have died on account of the intense heat, while the trees of the species *rostrata* and *rudis* have survived the heat and are making wonderful growths under irrigation.

The blue gum reaches its greatest development along the coast and river bottoms, where the annual rainfall is fifteen or more inches, and foggy days are common; although trees of this species are to be found growing on lands varying from an alkali to a rich loam, and at varying elevations from river bottoms to hilltops.

The lumber of this species is durable above ground, and is being sawed at San Jose, California, for the felloes, poles, reaches and singletrees of wagons, and flooring, insulator pins, and, in fact, anything that requires strength. It is valued at the same price as that of oak lumber, which it is slowly replacing. The wood is yellowish white in color, closed grained and easily polished. It has a tendency to chip when planed, on account of a wavy grain.

The leaves from the blue gum furnish practically all of the Eucalyptus oil in this country, as it is claimed by the distillers that it is the only species producing sufficient quantity of oil per hundred pounds of leaves to make distilling a profitable business.

This species, *Eucalyptus globulus*, is undoubtedly better known than any of the other eucalypts in this State, and is recognized generally in the State as one of the fastest growing trees in the world.

Mr. Abbot Kinney says of the *globulus:* The blue gum is a sort of average Eucalyptus, tall, but not the tallest; used for general purposes, even to piling and ship building; it is not the best of timber for any of these purposes; not the most lasting in the air, ground or water; not the highest yield of oil; not the best honey-making tree for bees. It is still well up in all of these respects. Like nearly all eucalypti the tree should be cut when the sap is least active and should be worked

FIG. 11.—Eucalyptus globulus. Natural size.

into its final form of firewood, boards, etc., as soon as possible after it is felled. I have seen blue gum logs become so hard that the cost, from increased difficulty of handling, ate up more than the final value. In many places this tree does well singly and in single lines, and it will furnish a continuous supply of firewood, as on the borders of fields and orchards that are cultivated, when it will amount to little or nothing in solid plantations. * * * A continuous supply of firewood can be obtained from the blue gum by pollarding or cutting the tree back every three or four years; it stands this treatment especially well while some of the other species do not take kindly to it. The sprouting of the blue gum when cut adds to its value as a fuel tree, for in all plantations it makes its first crop in about seven years and than for an indefinite period renews the crop every three or five years.

The *E. globulus* accommodates itself to more conditions in a satisfactory way than any other Eucalyptus. Yet there is no one condition for which some other species of this genus is not better adapted. So also there is no use to which the blue gum is put for which another species is not more serviceable.

Eucalyptus Gunnii. Swamp Gum Tree.

In the lowland along fertile valleys *E. Gunnii* attains a considerable size and supplies a strong, useful timber. It is this species that survived the severe frosts at Kew Gardens. Bees obtain unusually much honey from the flowers of this species. Cattle and sheep browse on the foliage. (Von Mueller.)

Mr. Abbot Kinney describes it as being a green, attractive looking and rapid growing tree and often a very fantastic grower in California, bending entirely over and sweeping the ground with its branches; it is one of the best frost resisters among the eucalypts but contains only a small per cent of oil.

Eucalyptus Robusta. Swamp Mahogany.

The swamp mahogany is one of the erect, but slow growing eucalypts. The trunks of the young trees are of a reddish gray color, slightly rough or stringy, while the limbs are smooth and dull red. The bark of the old trees is very rough, stringy and persistent.

The leaves are of a leathery texture, broad and lance-shaped, with the veins parallel and nearly at right angles to the midrib; in color they are dark green on the upper surface, while the under surface is several shades lighter.

The buds, with their deciduous calyx caps, are club-shaped and are borne in clusters of five to eleven. These clusters, or umbels, are axillary and their stalks are flattened. The mature seed cases are deep cup-shaped, with the valves enclosed.

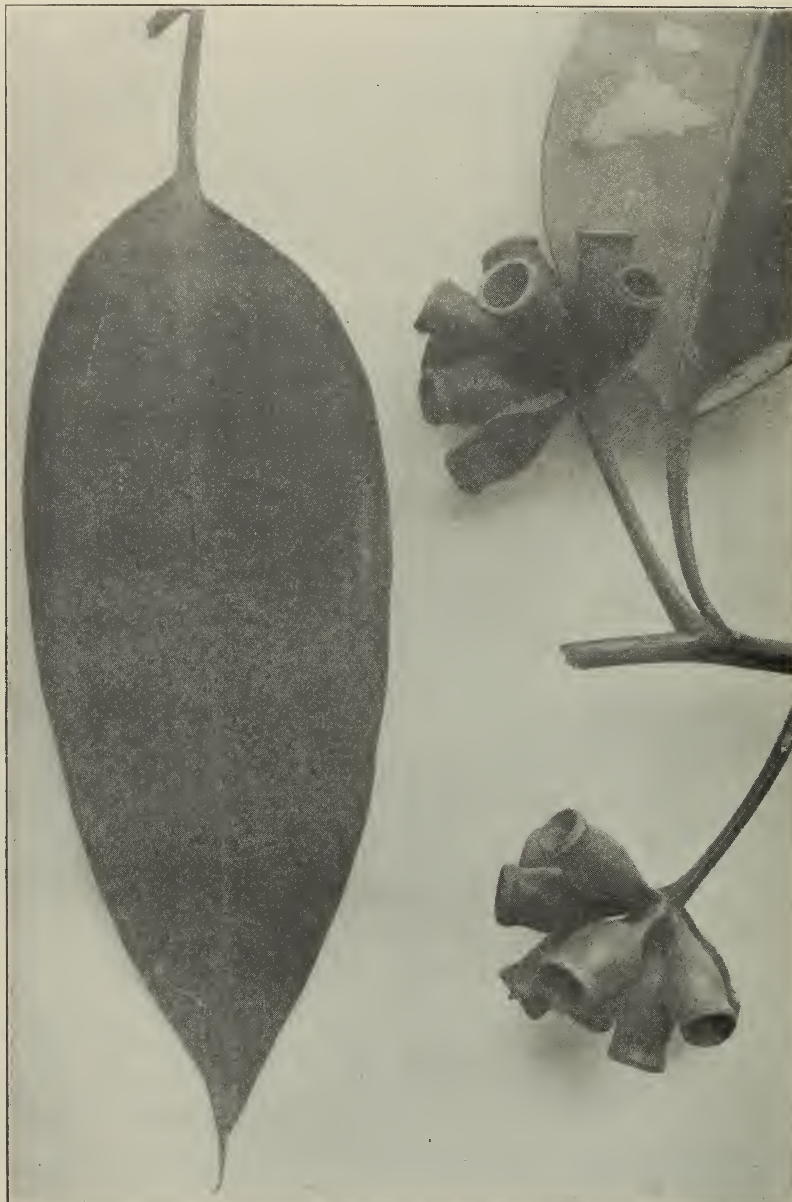

FIG. 12.—Eucalyptus robusta. Natural size.

The wood is not very valuable to work, as it is very brittle, but it is durable in the soil. The trees, if grown in a place exposed to the wind, are liable to break off when they have reached a height of from 15 to 30 feet.

Eucalyptus robusta is much used for street planting, and makes one of the best street trees to be found among the species of Eucalyptus, except for its tendency to break down. It will withstand low temperatures.

It reaches its greatest development where there is plenty of water, as in river bottoms, swamps and depressions in fields where the winter rains settle.

Eucalyptus Rostrata. Red Gum.

Trees of this species are of a slower growth than the blue gum and grow very crookedly even in close plantings.

The bark of the seedlings and the twigs of the old trees have a reddish hue, while that of the trunks of the mature trees is a very dark gray, varying from smooth and non-persistent in some trees to others where it is deeply furrowed and persistent. The limbs are much lighter than the trunk and smoother.

The leaves of the seedlings are broad lance-shaped, darker in color on the upper side, while those of the older trees are elongated, narrow, sickle-shaped, and equally green on both sides. The umbels are solitary and axillary. The flowers are borne in clusters of from three to fourteen, generally seven, in one fourth inch pedicels.

The buds, with their hemispherical, sharply-pointed lids, are nearly round and a little larger than a BB shot, valves three to five in number, generally four, very much protruding on the mature fruits.

The wood of the red gum is very durable both above and below ground and can be easily worked when green. It is possible to saw the wood up into the thinnest of lumber and veneers. In color the wood varies from a very light to a dark blood red. This is very heavy and takes a fine polish, but according to strength tests it is inferior to both sugar and blue gums.

The present range of *Eucalyptus rostrata* extends south from Chico, Butte County, in the Sacramento Valley, throughout the San Joaquin Valley, into the southern part of the State, and this species has shown its ability to stand the intense heat of the Imperial Valley throughout its entire length to Calexico on the Mexican border. In every instance where this tree was found in the Imperial Valley it was making a good growth, with proper care, notwithstanding the heat.

The red gum makes a good growth on alkali soils in the San Joaquin Valley and is one of our most drought resistant trees of any commercial

FIG. 13.—Eucalyptus rostrata. Natural size.

value, other than the sugar gum or *corynocalyx.* It is a slow growing species in regard to height, but one of the first in regard to diameter.

Baron von Mueller thus speaks of the *rostrata:* It attains exceptionally a height of 200 feet with a comparatively slight stem, but it is mostly of a more spreading habit of growth than the majority of its tall congeners. The timber is one of the most highly esteemed in all Australia among that of the eucalypts, being heavy, hard, strong and extremely durable, either above or under ground or in water. For these reasons it is very much prized for fence posts, piles and railway sleepers. For the latter purpose it will last at least a dozen years, but if well selected much longer. Indeed, sleepers were found quite sound after being 24 years in use. It is also extensively employed by ship builders for main stem, stern post, inner post, deadwood, floor timbers, transoms, knighthead, hawse pieces, bottom planks, breast hooks and riders, windlass and bow rails. It should be steamed before it is worked for planking. Also largely used for felloes, buffers, and posts and any parts of structures, which come in contact with the ground; not surpassed in endurance for woodbricks in street paving and for tramways.

Eucalyptus Rudis.

Trees of this species are erect, branching low in individual specimens, but having clean trunks in close plantings. The bark of the trunks is persistent, slightly rough, but not deeply furrowed; in color it is gray. The leaves of the young plants are oval and of a purple hue, while those of the old trees vary, oval to lance-shaped. The buds, with their blunt, cone shaped deciduous calyx caps, are borne on medium length stalklets, in clusters of from five to nine. The solitary umbels are axillary. The mature seed cases are broad cup-shaped, with the valves, from four to six in number, slightly protruding.

There are two different trees in the State recognized as *Eucalyptus rudis:* the tree called *rudis local* in the southern part of the State has a smooth-barked trunk, as a rule, and the wood is inferior, dark brown in color and light.

The species described grows in the vicinity of Fresno, and is a superior tree, with the wood of a light brown color, hard and easily polished.

The wood of this latter tree is very durable; there are records of posts standing in the ground for eleven years without signs of decay.

Eucalyptus rudis is capable of enduring low temperatures, as well as the *globulus.*

The *rudis* in Arizona called the desert gum, is reported by the experiment station (Timely Hints for Farmers, No. 68) as being one of the most rapid growing of the eucalypts, especially when young. At "Tucson it has shown itself extremely resistant to summer heat and winter cold, having never suffered therefrom; it is also drought resistant."

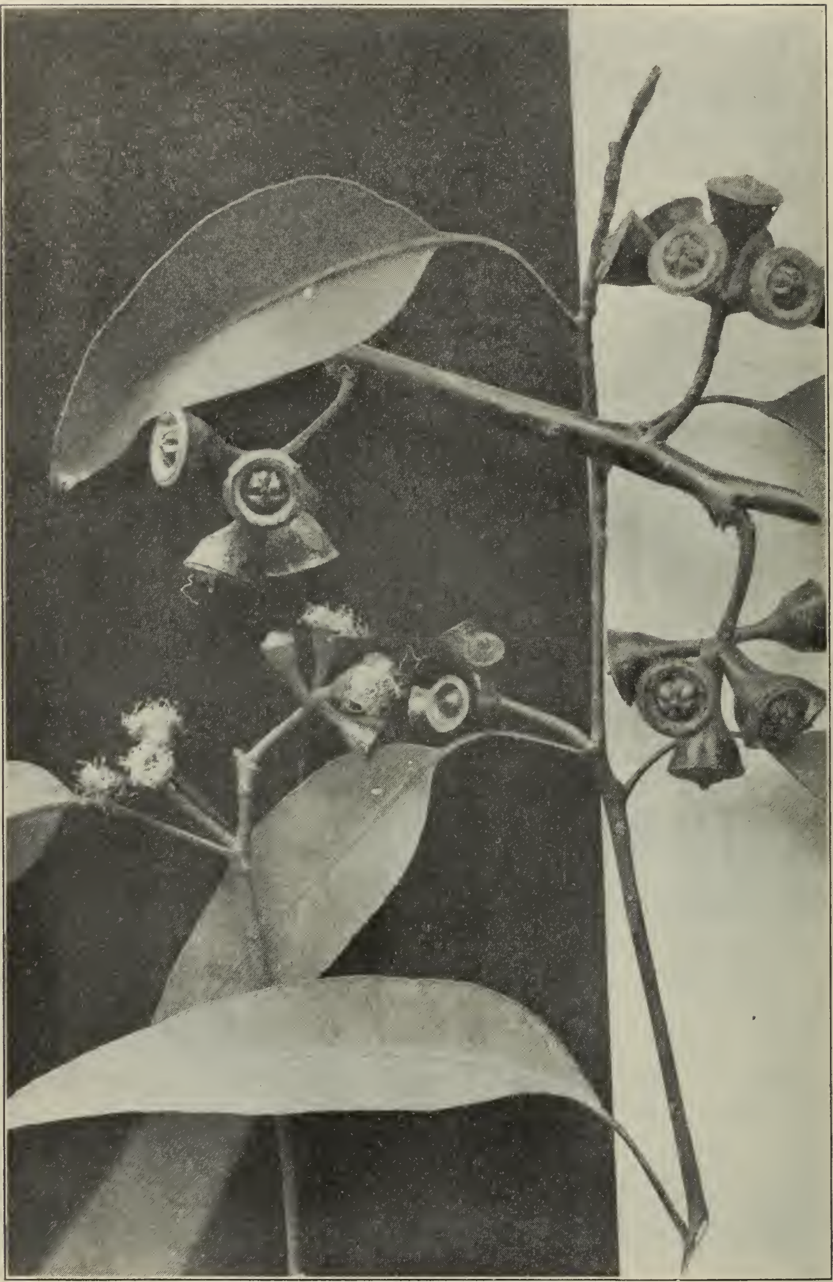

FIG. 14.—Eucalyptus rudis. Natural size.

Eucalyptus Sideroxylon var. **Rosea.** Victoria Ironbark.

This species has a tendency to grow crooked and branched. The black bark is deeply furrowed and persistent, giving to the trees a burned appearance, which is characteristic of this variety. The foliage of the tree is beautiful, of a bluish tint and pendulous, producing a weeping effect. The leaves are of medium width and length, of a light bluish green color. The buds are borne in solitary axillary umbels, in clusters of generally seven on one fourth inch stalklets. In shape they are cylindrical, with a conical calyx cap. The flowers are pinkish in color and in bloom from March to June.

The mature seed cases are deep cup-shaped with the rim compressed, and the valves, which vary from four to six, deeply enclosed. The wood of this species is of a dark brown color and particularly hard, heavy and durable.

Eucalyptus Tereticornis. Forest Gray Gum.

This species is of a very erect habit of growth, both in close plantings and isolated specimens. The branches are few and scattering, leaving the crown open. The deciduous bark of the trunks of the old trees is generally smooth and of a mottled color, from light brown to cream, directly after the bark has been shed. The buds are in bloom during May and June, and are borne laterally in solitary umbels, in clusters of from five to nine, on short stalklets. The deciduous lid is horn-shaped; reddish brown in color, just before blooming time.

The seed cases are slightly larger than those of *Eucalyptus rostrata;* with the valves, three to five in number, generally four, protruding and hemispherical. The leaves of the young plants are broad lance-shaped, while those of the old trees are long, of medium width and light green on both sides. The pendulous branches with their long leaves give to the trees a weeping effect. The wood of this species is close grained and durable, varying in color from a white to a light brownish red, and can be used in wheelwright's work, etc.

Undoubtedly *Eucalyptus tereticornis* can withstand as wide a range of temperature and of variation in soils, over as large a range of the State, as the red gum.

FIG. 15.—Eucalyptus sideroxylon. Natural size.

FIG. 16.—Eucalyptus tereticornis. Natural size.

Eucalyptus Viminalis. Manna Gum.

There are two varieties of this species, both erect-growing trees. The trunks of one variety have a bark not dissimilar to that of the *globulus* while that of the other has a smooth bark, white in color and deciduous. The bark is shed each year just as the trees are entering the blooming period. The leaves of the young plants and the sprouts of the old trees are from two to three inches long, narrow and opposite; while those of the old trees are long, narrow, slightly curved, of a dull green color, pointed and pendulous, giving to the trees a weeping effect. The stemless buds, with their conical, deciduous calyx cap, are borne in threes on slightly flattened stalks. The mature seed cases are goblet-shaped, with the valves, four in number, barely protruding.

The wood of the species is inferior to that of the red gum, both in strength and durability, although it is useful in rough carpentry, and in making fruit boxes, or any other light shipping boxes. In color the sap wood is light brown, changing to a yellowish white in the older wood.

The *viminalis* or manna gum withstands low temperatures equally as well as the red gum or the blue gum, and is growing at Chico, Butte County, in greater numbers than any other eucalypts.

Although this species is not a very valuable timber tree, it makes an average wood for fuel purposes, and can be grown on land under conditions where many of the other and more valuable species would barely live and make only an inferior growth.

Von Mueller in describing this species remarks that in the rich soil of the mountain forests of Australia it attains gigantic dimensions, rising to a height of rather more than 300 feet, with a stem occasionally 15 feet in diameter. It is the only species of eucalypt which yields the crumb-like melitose-manna copiously.

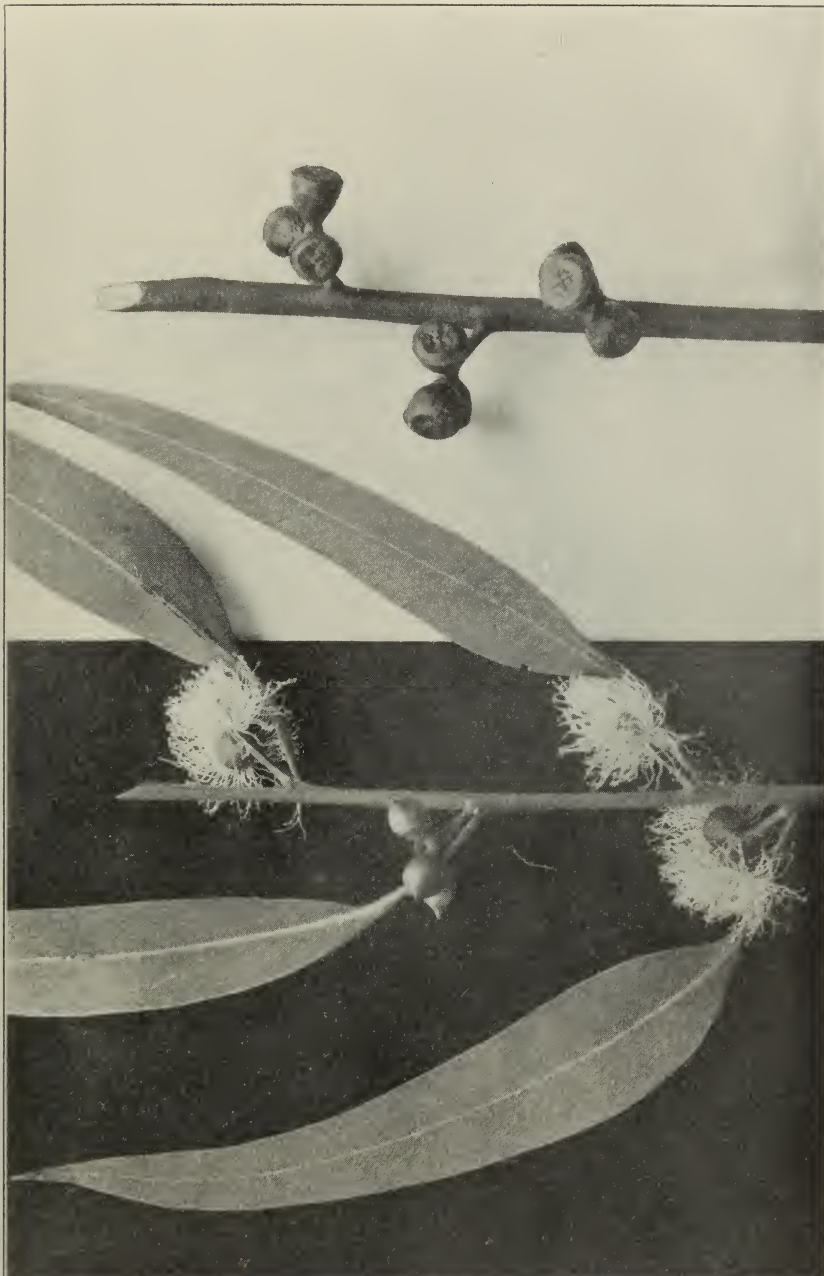

FIG. 17.—Eucalyptus viminalis. Natural size.